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CONSERVATION OF THE OIL AND GAS RESOURCES OF THE AMERICAS. PART I.[1]

RALPH ARNOLD.

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In preparing a paper of so wide a scope as the title of this one implies, it becomes necessary to seek information from first-hand sources if one wishes to make his data at all complete. The writer has been fortunate in having the hearty coöperation of many whose personal work is adding day by day to our general knowledge of the gas and oil fields of the Americas. Among those to whom he is particularly indebted are Dr. George Otis Smith, director of the United States Geological Survey; Dr. Eugene Haanel, Dr. R. G. McConnell, and Mr. Wyatt Malcolm, of the

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INTRODUCTION.

It is the purpose of the present paper to show the status and possibilities of the oil industry in each country of the Americas, and to discuss briefly some of the ways in which the oil resources of these countries can best be conserved. Gas will be mentioned only as it is incidental to the oil.

Before beginning the discussion it will be well to enumerate some of the factors that govern the production of oil and gas in all countries. These factors may be divided into two groups—natural factors and artificial factors. In the group of natural factors are rock pressure, or pressure under which the oil and gas exist in their underground reservoir; viscosity of the oil; and thickness, extent, porosity, and structure of the reservoir rock. In the group of artificial factors are the price of oil or gas, which is the dominant factor, and such others as depth of wells; time required to complete wells; distance separating wells; condition of wells, pumps and other equipment; improvements in methods of development and recovery; water complications; discovery of new fields; distance of fields from markets; transportation facilities; and relative cost of production in the several fields. These condi-

[2] *Petroleum World*, Vol. 12, February, 1915.

tions have all been briefly discussed in a paper[3] by the writer appearing in a recent number of this journal.

The relative rank as oil producers of the countries of the Americas with respect to one another and to the countries of other continents is shown by the following table, compiled by the United States Geological Survey.

TABLE I.

WORLD'S PRODUCTION OF CRUDE PETROLEUM IN 1914, AND FROM 1859 TO 1914, WITH PERCENTAGE OF PRODUCTION, BY COUNTRIES, IN BARRELS OF 42 GALLONS.

	Country.	1914.		1859–1914.	
		Production.	Per Cent.	Production.	Per Cent.
1	United States	265,762,535	66.36	3,335,457,130	59.63
2	Russia	67,020,522	16.74	1,622,233,845	29.00
3	Mexico	21,188,427	5.29	90,359,869	1.62
4	Roumania	12,826,579	3.20	117,982,474	2.11
5	Dutch East Indies	[a]12,705,208	3.17	138,278,392	2.47
6	India	[b]8,000,000	2.00	73,979,919	1.32
7	Galicia	[b]5,033,350	1.26	131,873,601	2.36
8	Japan	[c]2,738,378	.68	27,051,158	.48
9	Peru	1,917,802	.48	14,306,972	.26
10	Germany	[b]995,764	.25	12,965,569	.23
11	Egypt	777,038	.19	1,086,728	.02
12	Trinidad	643,533	.16	2,069,430	.04
13	Argentina	600,000	.15	600,000	.01½
14	Canada	214,805	.05	23,493,610	.42
15	Italy	39,548	.01	802,229	.01
16	Other countries	20,000	.01	722,000	.01½
		400,483,489	100.00	5,593,262,936	100.00

[a] Includes British Borneo. [b] Estimated. [c] Includes Formosa.

As nearly three fourths of the world's supply comes from North and South America, the tremendous influence they wield in this great industry is obvious, and in view of the fact that petroleum is a fundamental necessity of modern civilization, the strength of the new world's position becomes manifest. The countries of North and South America now hold relative positions in this industry indicated by the following order: United States, Mexico, Peru, Trinidad, Argentina, Canada, Venezuela, Colombia, Bolivia and Ecuador.

[3] Arnold, Ralph, "Petroleum Resources of the United States," ECON. GEOL., Vol. X., p. 695.

OIL FIELDS OF NORTH AMERICA.

Indications of petroleum are found in most of the countries of North America. The United States and Mexico are the largest producers, and Canada yields a small quantity, but the other countries are non-productive at present.

NEWFOUNDLAND.

Petroleum was first discovered in Newfoundland in 1812, but no effort was made to develop it for over half a century. The petroleum-bearing area of Newfoundland is confined to its west coast, the principal localities, according to Redwood, being at Port au Port Bay and from Bonne Bay to Sandy Bay. The reservoir rocks are the porous Lauzon limestones and Levis sandstones of the Quebec group, of Ordovician age. The oil is of brown color, light gravity, and paraffin base and ranges from 36° to about 46° Baumé (0.843 to 0.798 specific gravity). Development has consisted in the sinking of four or five wells at Parsons Pond, 100 miles northeast of Port au Port Bay. The deepest well attained a depth of 1,500 feet but found only a fair showing of oil. Other wells put down at Port au Port Bay yielded small quantities of a light paraffin-base oil. No commercially important deposits of petroleum are belived to exist in this island.

CANADIAN OIL FIELDS.

General Features.—The oil-producing territory of Canada is confined at present to the province of Ontario, where an area of about 25 square miles of proved land yields the total annual output of a little over 200,000 barrels of oil. Extensive areas in western Canada, however, offer indications suggesting the presence of oil in commercial quantities, and it is believed that the future will see the Dominion take its place as an important producer of petroleum. The oil-yielding formations are of Ordovician to Carboniferous age in the east and of Cambrian, Devonian, and Cretaceous age in the west. The oil is usually found in sandstones, limestones, or dolomites, associated with anticlines and domes. It ranges from the heavy oil of asphaltic type in

Athabasca to the high-grade refining oils of 36° to 46° Baumé (0.8434 to 0.7955 specific gravity) of the Ontario field. The initial production of individual wells has never gone above 7,500 barrels daily; the present average per well is only a few gallons. The product is used entirely within the country.

Nova Scotia.—Oil seepages occur in the Carboniferous shale and sandstone around Lake Ainslie, on Cape Breton Island, in Nova Scotia, but shallow borings made here have not been rewarded by production. This evidence and the paucity of indications elsewhere in the province leads to the conclusion that it will never yield oil in commercial amounts.

New Brunswick.—The proved oil territory of New Brunswick occupies an area of about two and one half square miles. It lies on the west bank of Petitcodiac River, between Stony Creek and Weldon Creek in Albert County. The oil occurs in sandstone beds, which are possibly in the nature of lenses in the shales of the Albert series of the Carboniferous system. The oil has a paraffin base, is free from sulphur, and ranges in gravity from about 32° to 37° Baumé (0.862 to 0.838 specific gravity). The production of the wells is small. Considerable quantities of gas accompany the oil. Indications of petroleum have also been found along anticlines in Kings and Westmoreland counties. To judge by the results of drilling in this province it does not seem probable that large deposits of petroleum will be found here.

Quebec.—Discoveries of gas in commercial quantities and indications of petroleum have stimulated prospecting in Quebec over a long period of time. Gas is found at St. Hyacinthe, St. Grégoire, Beauséjour, and in insignificant quantities elsewhere; evidences of petroleum occur on the Saguenay, Dartsmouth, York, St. John and Malbey rivers. The area chiefly explored lies in the basin of York River as far west as Falls Brook. The hydrocarbons are found at one place or another through the entire geologic series from the Trenton limestone (Ordovician) to the lower Devonian, but the upper formations yield the most favorable evidences for commercial deposits. The oil indications are usually associated with anticlinal structure. The oil is mostly of

high grade, ranging between 18° and 46° Baumé (0.948 to 0.795 specific gravity). Development has been carried on intermittently for a period of over forty years in the Gaspé field, but no uniformly commercially successful results have been realized, although some deep wells have been sunk. It does not appear probable that the province will ever yield more than very small quantities of oil.

Ontario.—The petroliferous fields of Ontario, the most important oil-producing province of Canada up to the present time, form a northeastward continuation of the Ohio-Indiana field of the United States. The producing oil fields are limited to that section of the province lying south of a line drawn from the west end of Lake Ontario to the foot of Lake Huron, and most of the oil produced comes from Lambton, Kent, Elgin, and Brant counties. The Oil Springs pool covers two square miles, and the Petroleo field covers 26 square miles. None of the others cover more than a few square miles, and the total proved area of the district probably does not exceed 50 square miles. The formations yielding oil and gas range from the Trenton (Ordovician) to the Chemung group (Devonian). The chief source of oil is the Onondaga limestone of the Devonian, and the principal deposits of gas are found in the Medina sandstone and Trenton limestone. The Tilbury field derives its oil from the Salina formation and Guelph dolomite of the Silurian. The rocks as a rule are nearly horizontal and are covered by a great thickness of drift. Domes are the principal structural features affecting accumulation in these fields, although locally porous lenses or pockets and crevices afford sites for commercial deposits of oil. The wells range in depth between 300 and 500 feet and in production from an individual initial yield of 7,500 barrels daily, in one of the wells drilled in the sixties, down to the average of a fraction of a barrel a day now maintained by the wells of the district. The Ontario petroleums are rich in lubricating oils and give good yields of paraffin; those of Lambton County run as high as 2.5 per cent. in sulphur. The Lambton County oils range in gravity from 31° to 35° Baumé (0.8696 to 0.8485 specific gravity); those

of Tilbury from 38° to 41° Baumé (0.8333 to 0.8187 specific gravity). The relative importance of the Ontario pools is shown in the following figures of production furnished by Mr. Wyatt Malcolm, of the Canadian Geological Survey:

TABLE II.

PRODUCTION OF PETROLEUM IN ONTARIO.

	1906.	1910.	1914.
Lambton County	377,286	205,456	154,186
Bothwell field	44,827	36,998	33,961
Tilbury and Romney	106,992	63,058	18,530
Dutton	19,376	7,752	1,190
Onondaga		1,005	2,437

There are a few other fields of small yield, and a few that have produced small quantities of petroleum but are now exhausted. The total production of Canada in 1914 was 214,805 barrels, practically all of which came from Ontario.

In view of the facts that all the favorable localities in the Ontario field have been pretty thoroughly prospected and that the decline of the present pools suggests that the production will sink to rather insignificant quantities within a comparatively short time, it is evident that this province, like all of the others in eastern Canada, is destined to play but a very minor part in the oil industry of the future.

Calgary or Foothill Field.—The Calgary or Foothill field received more attention and gained more notoriety during 1914 than any other oil region in North America. It includes the narrow belt of sharply folded and faulted Cretaceous rocks that extends for 500 miles northwestward along the eastern foot of the Rocky Mountains from the international boundary into northeastern British Columbia, and the parallel wider belt of low, broad domes and folds, also developed in the Cretaceous rocks, in the plains country of southern Alberta and Saskatchewan. Oil has been found in noteworthy if not yet commercially remunerative quantities in shale formations above the Dakota sandstone along the crests of sharply folded anticlines in the narrow belt near Cal-

gary, and gas is being recovered in commercial quantities from beds at practically the same horizons in the broader folds in the plains region about Medicine Hat. The oil from the Calgary wells ranges from 38° to 62° Baumé (0.8333 to 0.7290 specific gravity), and the highest-grade oil is a very unusual natural product. The output of the few wells that have struck oil in the Calgary region has not yet been thoroughly tested, as the best wells have produced only a few hundred barrels in all. It is the writer's opinion that the area of commercial productivity will be confined to a few square miles along the crests of locally favorable anticlines and that the product, though small in quantity for individual wells, will for the most part be an oil of unusually high grade.

Athabasca or Tar Sand Field.—The Athabasca or Tar Sand field includes the area in northern Alberta extending from a locality a short distance north of Edmonton to the lower reaches of Athabasca River. Throughout portions of this region Devonian limestone is unconformably overlain by asphalt-saturated sands or tar sands of Cretaceous age. These sands are in places as much as 200 feet thick, and, according to Bosworth, cover an area of at least 2,000 and possibly 10,000 square miles. If uniformly saturated they would contain 200,000 million tons of oil, enough to satisfy the world's demand at the present rate for 2,000 years. A few wells, one at least 1,750 feet deep, have been put down in the Tar Sand region, and considerable gas and a little oil have been recovered. The oil is black and viscous and yields unusual percentages of gasoline, kerosene and lubricants for its relative specific gravity. Owing to the poor transportation facilities and the rather unfavorable structural conditions for the accumulation of oil in the localities so far examined, little will probably be done toward the immediate development of this region, but as a potential source of hydrocarbons it must certainly be taken into account. Those who are best acquainted with it are the most enthusiastic over its possibilities.

Northwest Territories.—According to Bosworth the region between Peace and Athabasca rivers and the Arctic Ocean, covering

200,000 square miles, is occupied largely by Devonian limestones and shales which at many points yield direct evidences of petroleum in the form of seepages, burnt shale, etc. The structure is locally favorable for the accumulation of oil, broad anticlines prevailing over extensive areas. The oil is apparently of light gravity and excellent quality. No wells have yet been drilled in the region to test its commercial possibilities, and although it is at present isolated from the markets of the world by hundreds of miles of trackless wilderness, it must, like the Tar Sand field to the south, be regarded as a possible source of future supply of oil for North America.

British Columbia.—The British Columbia or Rocky Mountain field, as at present known, occupies the extreme southeast corner of British Columbia and the extreme southern part of Alberta and extends across the international boundary into Montana. The region is that of the great overthrust fault which has forced the mountain-making mass of Cambrian rocks out over the Cretaceous strata of the plains province. On Sage Creek and other adjacent tributaries of Flathead River, on the west, and on Pincher Creek, on the east, well-defined anticlines in the Cambrian beds yield seepages of a light oil, and wells drilled at both localities have produced petroleum of approximately 40° Baumé (0.8235 specific gravity). The oil from Sage Creek is of a peculiar milky color and an unusual composition for a natural oil and supports the theory that it has been derived by filtration from the Cretaceous beds underlying the Cambrian in the area of the thrust fault. It is the writer's belief from personal examination that not more than four or five square miles of this field, at the most, may prove productive, and that this area will be made commercially productive only by the most careful management.

UNITED STATES.[4]

General Conditions.—The oil fields of the United States are fairly well distributed geographically, occupying areas from the

[4] Details concerning the oil fields of the United States were covered in the paper mentioned in the footnote on page 204, so that only a general statement will be included here.

Appalachian Range on the east to California on the west, and from the Canadian boundary on the north to the Mexican line on the south. They are usually classified as the Appalachian, Lima-Indiana, Illinois, Mid-Continent, Gulf, Rocky Mountain, California, and Alaska fields. Their proved area includes over 4,100 square miles; the prospective territory nearly 1,000 square miles. The production for 1914 was 265,762,535 barrels; the total production to 1914 was 3,335,457,130 barrels; the estimated future supply is 5,763,100,000 barrels. The oil is found in formations ranging in age from the Ordovician to the latest Tertiary and Quaternary, usually in sandstones or limestones. Practically all types of structure are present in the productive areas, but anticlines and domes predominate. In quality the oil ranges from the asphalt-base oils of California and Texas, whose gravity is from 10° to 35° Baumé (1.000 to 0.8485 specific gravity), to the lightest paraffin-base oils of the Eastern States, whose gravity is from 25° to 52° Baumé (0.9032 to 0.7692 specific gravity). The maximum production of individual wells for most of the fields is less than 10,000 barrels daily, although there have been daily records of 58,000 barrels in California and 75,000 barrels in Texas. The wells range in depth from 200 to more than 6,000 feet. Old pipeline transportation systems extend for hundreds of miles in certain parts of the country.

MEXICO.

General Features.[5]—The known oil fields of Mexico are included within two great regions, both of which are segments of the Gulf Coastal Plain—the Tampico-Tuxpam and Tehuantepec-Tabasco regions. The Tampico-Tuxpam region is the larger and better known and consists of that part of the Coastal Plain tributary to and depending mostly for supplies on transportation through the ports of Tampico, in the State of Tamaulipas, and Tuxpam, in the State of Vera Cruz. It covers approximately that part of the Coastal Plain between Soto la Marina and Tecolutla

[5] This section is copied practically verbatim from statements kindly prepared for the writer by Mr. John S. McKenna, under the direction of Mr. V. R. Garfias, and by Mr. E. De Golyer.

rivers, an area of some 20,000 square miles. In includes parts of the States of Tamaulipas, Vera Cruz, San Luis Potosi, Puebla, and Hidalgo and embraces some fifteen oil fields. The Tehuantepec-Tabasco region consists of that part of the Coastal Plain included in and between the valleys of the Coatzacoalcos and Grijalva rivers and includes parts of the States of Vera Cruz, Tabasco, and Chiapas. This region embraces some four or five oil fields. A very rough estimate places the proved area in the two regions at 25 square miles; the prospective area at 500 to 1,000 square miles.

Exploration has advanced too little and the Mexican fields are too young to justify any but approximate estimates of the proved, probable, or possible oil territory in each field, nor are such estimates of much value, even for comparative purposes, without a full consideration of other factors that are as yet undetermined. Inasmuch as less than 700 wells have been drilled for oil in the entire Republic up to the present time and as almost two thirds of the entire quantity of oil produced has come from two wells, neither of which is more than six years old, it would be rash indeed to give too much weight to estimates of unit areas.

The principal oil-yielding rocks in the Tampico-Tuxpam region are the Tamasopo limestone, of Cretaceous age, and the overlying San Felipe series, of Cretaceous or Eocene age. The oil in the San Felipe rocks has apparently migrated from the underlying Tamasopo through faults, fissures, and broken contact zones between sedimentary and intrusive rocks. Some oil is found in the overlying Mendez shale, of Eocene age, and the Oligocene limestones which overlie the Eocene. This oil also is evidently derived from the Tamasopo limestone. The oil-bearing rocks of the Tehuantepec-Tabasco region are true quartz sands of Miocene (?) and Pliocene age.

The Tamasopo limestone, the principal oil-yielding rock, is a massive-bedded, fossiliferous, hard, porcelain-like limestone. It is locally porous or cavernous as a result of solution. It is not dolomitic but is somewhat siliceous. The overlying San Felipe beds are a series of alternating impure limestones and shales, in

which the oil occurs to some extent in porous limestone members but more generally, perhaps, in interstices in the shales. Many wells that are apparently finished in the San Felipe draw their major oil supply from the Tamasopo limestone through fissures. Potrero No. 4 was finished in the San Felipe, but a great number of blocks of Tamasopo rock were blown out when the well came in.

The fields of the Tampico region are generally anticlinal in structure, so far as is known; the San Diego, Casiano, Naranjos, Tierra Amarilla, Potrero and Alamo fields being markedly so. The structure of the Topila, Panuco, Ebano, Chijol and Chila Salinas fields is not determined, but it is probable that they are the result of the filling of porous beds in the San Felipe formation through fissures that extend to the Tamasopo, and that the structure is not a vital factor in the accumulation of the oil deposit. The Furbero field is structurally a laccolith or sill intruded into the Mendez shales on a preexising anticline. The shales were metamorphosed by the intrusion and the igneous rock of the sill was subsequently altered, thus providing pore space. The oil evidently came from the Tamasopo limestone.

The oldest Mexican field dates as an important producer from 1906, the Isthmus fields from 1907, and the most productive fields from the later part of 1910. There are almost no data to be had regarding the life of a field or of a well. Laguna No. 2 of the Ebano field came in November 7, 1906, with an initial production of 500 barrels a day. Five years later, in December, 1911, it was producing 450 barrels a day. No information is available regarding the larger wells, for the potential production so far exceeds the actual production, because of a lack of transportation facilities, that for many wells the true capacity, initial, potential, or present, is unknown. The largest gaged production is that of Potrero No. 4, at some 110,000 barrels daily. Casiano No. 7 has yielded a total production to the present time of some 40,000,000 barrels, with no apparent sign of decline.

The following table shows the range in production of individual wells and the present daily production by districts.

TABLE III.

RANGE IN PRODUCTION OF INDIVIDUAL WELLS, AND DAILY PRODUCTION BY DISTRICTS.

District.	Range in Daily Production per Well. *Barrels.*	Net Present Daily Production for the District. *Barrels.*
Ebano	50– 5,000	5,000
Panuco	50–100,000	20,000
Huasteca	50–110,000	45,000
Tuxpam	50– 10,000	10,000
		80,000

The bulk of the oils at present produced commercially are heavy oils of mixed asphalt and paraffin base. The oils of the Tehuantepec-Tabasco region are the lightest, their gravity ranging from about 15° to 29° Baumé (0.964 to 0.882 specific gravity). The oils of the Tampico-Tuxpam region are somewhat heavier and fall into two general classes, the heavy oils of the Panuco River valley fields, with gravity of nearly 10° to 14° Baumé (0.896 to 0.972 specific gravity), and the lighter oils of the Casiano, Potrero, Furbero, and other fields, with gravity of 19° to 26½° Baumé (0.940 to 0.900 specific gravity). A very high grade oil, about 49° Baumé (0.783 specific gravity), has been discovered south of Valles, in San Luis Potosi, but revolutionary disturbances have precluded the development of this deposit up to the present time.

The oil is usually accompanied by and associated with a considerable quantity of gas, all "wet" so far as known. White estimates that 10,000,000 to 12,000,000 cubic feet of gas is produced daily by Casiano No. 7, and it is probable that a like quantity is produced at Potrero. A well in the Topila field came in last May with an estimated daily flow of 15,000,000 cubic feet of "wet" gas. The Alamo field is said to have a potential daily production of 4,000,000 to 6,000,000 cubic feet of "wet" gas.

The depth of the producing wells of the Tampico-Tuxpam region ranges from 113 feet, in Tanhuijo well No. 1, to 4,000 feet, in San Pedro well No. 1, though most of the large producers are between 1,600 and 2,500 feet deep. Exploratory wells 3,000

to 4,000 feet deep are not uncommon, and Furbero No. 19, the deepest well in Mexico, has reached a depth of 4,640 feet. The wells of the Tehuantepec-Tabasco region are relatively shallow.

The following table summarizes information about the operating companies and wells:

TABLE IV.

OPERATING COMPANIES AND WELL DATA, MEXICO.

District.	Companies.	Wells Producing.	Wells Being Drilled.	Dry Holes or Abandoned Wells.	Idle Wells.	Depth (Feet).
Huasteca	11	28	27	40	24	1,700–3,000
Ebano	1	5	.....	.....	22	1,500
Tuxpam	1	2	5	1	.....	2,000
Panuco (Topila)	16	[a]23	11	9	.....	2,600
Panuco (Panuco)	46	[a]60	57	12	.....	.....
Panuco (other fields)	4	2	1	1	11	770–4,000

[a] Completed.

Both the rotary-hydraulic and standard cable systems of drilling are used. The former is particularly efficient and rapid in drilling through the great shale formation which overlies the oil zone; the latter is most efficient for drilling the alternating shales and limestones of the San Felipe series and the hard limestone of the Tamasopo, the producing formations. Though both systems are used for the entire completion of wells, a combination of the two is generally regarded as most efficient and is in general use. The Canadian pole tool and Fauck systems have each been tried in this region but, as they present no decided advantages and it is difficult to obtain repairs, spare parts, etc., they have been abandoned.

The first and most general use for Mexican crude oil, aside from supplying oil for refining, for local trade, has been as a fuel oil. More than half the oil produced in Mexico is exported to the United States, where it is used for the most part as fuel oil. Shipments are also made to Central and South American and European ports. Considerable quantities of refined oils, including fuel oil, are exported to Great Britain. Asphalts, road oils, and similar products are exported to Canada, the United States, and Europe. The present tendency, with the increased refining

facilities at Tampico and the better development of refining practice both in Mexico and in the United States, is to top the crude oil before using it for fuel and thus save the lighter and more valuable constituents.

Several American and European financial groups interested in the petroleum industry are represented in the Mexican fields.

The Mexican Petroleum Co., Ltd., and its subsidiaries (Doheny interests) are at present the largest producers and best equipped as regards camps and facilities for transportation and storage. Their product is sold mostly in bulk to American companies along the Gulf States. Of late this company has undertaken to market its products in the United States and has established distributing depots at New York and on the Mississippi River not far from New Orleans.

The Aguila Oil Co. and its subsidiaries (Pearson interests) have a larger nominal production than the Mexican Petroleum Co., but are somewhat hampered by insufficient pipe-line and storage facilities. The oil is refined at their Minatitlan plant, the products being sold in Mexico and exported to Europe. This company and the Mexican Petroleum Co. furnish practically all the oil used in Mexico and the greater portion of that which is exported.

The Waters-Pierce Co (Standard Oil) has a refinery at Tampico, where Mexican and American crude oils are treated, and producing wells in the Panuco district. This company and the Aguila control the market for refined oils in the Republic.

The Corona Oil Co. (Dutch Shell), East Coast Oil Co. (Southern Pacific), Pennsylvania Mexican Fuel Oil Co. (Standard Oil) and other concerns have strong affiliations and ample market facilities in the United States and Europe and thus are able to dispose of their Mexican products regardless of the local market. Most of the lands controlled by these companies are located in the Panuco and Tuxpam districts.

Besides the groups just enumerated there are several independent companies that have no affiliations with any of these groups and depend on small contracts and the local market for the dis-

posal of their products. The lands controlled by some of these companies are located in the Panuco and Huasteca districts, in comparatively small tracts, many of them scattered over large areas. The boom time for operators of this type is practically over, and the bulk of the oil industry in Mexico has passed into the hands of large financial interests.

The following figures of production of crude oil in Mexico were compiled by Miss Anna B. Coons of the United States Geological Survey.

TABLE V.

PRODUCTION OF CRUDE OIL IN MEXICO, 1904 TO 1914.
(In barrels of 42 gallons.)

1904	220,653
1905	320,379
1906	1,097,264
1907	1,717,690
1908	3,481,610
1909	2,488,742
1910	3,332,807
1911	14,051,643
1912	16,558,215
1913	25,696,291
1914	21,188,427
	90,153,721

Soto la Marina Field.—The northernmost oil field in Mexico takes its name from Soto la Marina River. It is in the State of Tamaulipas, 15 to 20 miles from the coast and 100 miles north of Tampico. The oil in this field is found in the porous limestone of the San Felipe series (Cretaceous and Eocene). Some oil may occur under laccoliths or lava flows above the main producing horizon. No well-defined structure other than the easterly monoclinal dip is observed in the field, the dominant structural factors of accumulation being basalt intrusions, laccoliths and faults. The oil averages about 18° Baumé (0.9459 specific gravity). Two wells are now being drilled in this field and have attained a depth of 3,000 feet, but oil in commercial quantities has not yet been encountered.

Tamasi Field.—The Tamasi field includes all the more or less

prospective areas between Los Esteros, on the Mexican Gulf Railroad, and the valley of Tamasi River, 20 to 30 miles northwest of Tampico. The oil comes from fracture zones in the lower Mendez marl (Eocene) and limestones in the San Felipe formation (Cretaceous and Eocene). Toward the northwestern part of the field anticlines appear to play an important part in the accumulation of the oil, but the southwestern part is more probably affected by fracturing and faulting. The oil is very heavy, ranging from 10° to 14° Baumé (1.000 to 0.9722 specific gravity). The production of the wells is so small and the oil so heavy that it is commercially worthless under existing marketing conditions.

Ebano Field.—The Ebano is the oldest of the fuel-oil fields and is on the Mexican Central Railway 40 miles west of Tampico. It includes about 4 square miles of proved ground, the few tests so far made outside of the producing area have not proved successful. The oil comes from the limestone and fracture zones in the San Felipe (Cretaceous and Eocene), the accumulations being largely determined by volcanic necks and fault zones. The oil ranges in gravity from 10° to 14° Baumé (1.000 to 0.9722 specific gravity). Wells yielding as much as 5,000 barrels a day have been recorded in the field; but the settled production runs from 25 to 5,000 barrels daily per well. La Paz No. 1 has averaged 1,500 barrels daily since April, 1904. The wells range in depth from 1,500 to more than 2,000 feet. The oil has been used principally for fuel on the railroads and for the manufacture of asphalt.

Panuco-Topila Field.—The most important of the northern fields is the Panuco-Topila, which extends along Panuco River from 20 to 30 miles west of Tampico. The proved area embraces about 4 square miles; the possible territory includes at least 10 square miles. The oil is obtained in the San Felipe (Cretaceous and Eocene) but probably comes from the underlying Tamasopo limestone (Cretaceous) through fissures. The range in gravity is 10° to 14° Baumé (1.000 to 0.9722 specific gravity). An initial flow of over 100,000 barrels daily has been recorded for one well; the settled production ranges from 50 to 100,000 barrels daily. The average daily production per well, for the wells now

being operated in the field, is about 250 barrels. The wells range in depth from 1,800 to 2,600 feet. The oil is all marketed through Tampico and is used largely for fuel and the manufacture of asphalt. On account of its great viscosity, which renders pipe-line transportation unsatisfactory, the oil is sent down the river in barges. Transportation is the factor at present governing the production of this field.

Valles (San Pedro) Field.—The small Valles or San Pedro field lies in the belt of Tertiary rocks 80 miles west-southwest of Tampico. The proved area includes a quarter of a square mile; the possible territory 1 to 2 square miles. The oil comes from the crest of an anticline in alternating limestones and shales of the San Felipe (Cretaceous). It averages about 48° Baumé (0.783 specific gravity) and is light colored and extremely volatile. The daily production of individual wells ranges from 50 barrels initial to 10 barrels settled. The wells are about 4,000 feet in depth.

Huasteca District.—All the fields lying between the valleys of Panuco and Tuxpam rivers, southwest of Tampico, among which are the Tanhuijo, Tierra Amarilla, Juan Casiano, Cerro Azul, Potrero del Llano, and Los Naranjos fields, are included in the Huasteca district. This district occupies a belt about 80 miles in length and 30 miles in average width, or a total area of 2,500 square miles. The proved areas include about 15 square miles; the possible territory at least 500 square miles. The oil is obtained from beds at various horizons from the Tamasopo limestone (Cretaceous) to the Tuxpam impure limstones and sands (Miocene). The enormous producers, all of which yield medium-grade oil of 19° Baumé (0.9395 specific gravity), obtain oil from the porous and cavernous limestones at the lower horizons. The sandstones and limestones at the upper horizons yield smaller quantities of a higher-grade oil—26° to 29° Baumé (0.8974 to 0.8805 specific gravity). Broad anticlines with numerous faults and igneous intrusions of various types appear to dominate the commercial accumulations. The initial production of individual wells yielding the medium-grade oils reaches 110,000 barrels a day, the capacity for settled controlled production ranges from 50 to 110,000 bar-

rels daily, and the average daily production is at least 1,600 barrels per well. The production of the wells yielding high-grade oil ranges from 300 barrels initial down to 25 barrels settled. The oil is marketed through Tampico and Tuxpam and is used principally for fuel, with minor quantities being refined. The wells tapping the upper (Tertiary) beds range in depth from 100 to 500 feet; those reaching the lower horizon from 1,800 to 2,500 feet.

South Tuxpam Field.—The South Tuxpam field includes the areas south of Tuxpam River, such as Furbero and Alamo, covering about 800 square miles. The proved territory is less than 1 square mile; the prospective territory about 50 square miles. The oil at Alamo comes from the Tamasopo (Cretaceous) limestones, probably in an anticline, and that at Furbero from Eocene marls associated with a laccolith or sill. The oil ranges from 18° to 26° Baumé (0.9459 to 0.8974 specific gravity). The range in individual daily production is from 20,000 barrels initial (Alamo) to less than 100 barrels settled (Furbero). The wells are from 1,700 to 2,500 feet deep. The oil is marketed at Tuxpam for fuel and refining.

San Cristobal Field.—The San Cristobal field is about 40 miles inland from Coatzacoalcos, in the Isthmus of Tehuantepec, and includes some subsidiary fields, such as Jaltipan. Its areal extent is about 20 by 5 miles, or 100 square miles. The proved area is less than 1 square mile; the prospective area is rather small. The oil-yielding rocks are lower to middle Tertiary sandstones; the dominant structures are well-defined elongated domes. The oil ranges in gravity from 25° to 32° Baumé (0.9032 to 0.8642 specific gravity). The individual daily production runs from 500 barrels initial to 50 barrels settled; an average at the present time is about 50 barrels. The market for the oil is the Minatitlan refinery. The wells are from 300 to 1,000 feet in depth.

Macuspana-Chiapas Field.—The Macuspana-Chiapas field includes areas in south-central Tabasco to the borders of Chiapas. The petroliferous territory includes about 20 square miles, of which about a quarter of a square mile is proved. The oil comes from middle and upper Tertiary sandstones in monoclinal and

anticlinal structure. The range in gravity of the oil is 30° to 40° Baumé (0.8750 to 0.8235 specific gravity); the average daily production is about 10 barrels to the well. Little of the oil has been marketed, and the field is temporarily idle. The wells range in depth from 100 to 2,000 feet.

Campeche Field.—Recent test drilling at Rancho el Chapopote revealed promising indications of an oil field near Campeche in the State of Campeche.

Conclusions.—No one can read even the most moderate statement regarding the Mexican oil fields without being impressed by their wonderful potentiality. There are a dozen wells in Mexico which, if opened to their full capacity, could almost double the daily output of the world. Political disturbances and difficulties of transportation have governed the production in Mexico since the large wells were brought in, so that no adequate estimate of total capacity can be made. It is certain, however, that the Mexican fields are destined to control the fuel situation on this side of the Atlantic Ocean for a long time to come, and that it is simply a question of transportation facilities and markets that will determine whether these fields are to produce as much or more than the combined fields of the United States. As to the longevity of the wells, no one can predict with certainty. When a well or group of wells begins to drop in production its decline will probably be rapid, for all the evidence in hand leads to the conclusion that water surrounds and underlies the productive areas and zones, and when the oil is gone from any reservoir the incoming water will terminate its productivity forever.

(*To be continued.*)

GARNET DEPOSITS ON THE NAVAJO RESERVATION, ARIZONA AND UTAH.

HERBERT E. GREGORY.

INTRODUCTION.

On the basis of economic importance garnets fall readily into two groups: abrasive and gem stones. They are all essentially silicates of aluminium and ferric iron with varying amounts of calcium, magnesium, ferrous iron, and manganese, and normally occur in metamorphic rocks, of which they may be the chief constituent. The calcium-aluminium garnet (grossularite), the calcium-ferric garnet (andradite), and the ferrous aluminium garnet (almandite) occur in abundance and are extensively mined as abrasives. At most localities the garnets are small but in the Adirondacks mines masses five feet in length have been found, and single crystals weighing as much as 20 pounds have been reported from Burke and Jackson counties, North Carolina. Their splintery fracture, which prevents the formation of a smooth surface, renders garnets suitable for use as "sand paper" and "emery wheels" particularly in polishing leather and wood. For a number of years past commercial production of garnets for abrasives has been confined to New York, North Carolina and New Hampshire, which states, in 1913, furnished a supply of 5,308 short tons valued at $183,422. Mining consists essentially in quarrying the garnet bearing rock, crushing it and separating the garnets by washing.

In the list of gem stones four varieties of garnet are included: almandite, containing iron and aluminium, the so-called "precious garnet"; pyrope, a magnesium-aluminium garnet; rhodolite, found only in North Carolina, and having a composition intermediate between almandite and pyrope; and spessartite, an exceedingly rare manganese-aluminium garnet. The most abundant

garnet of gem quality is the pyrope, which under the names of "Bohemian garnet," "Cape ruby," and "Arizona ruby" is widely used by jewelers.

In curio and jewelry stores in various cities of Colorado, Utah, Arizona, New Mexico and California, "Arizona rubies" are offered for sale, both as uncut stones and cut gems. In the stores along the San Juan River and at trading posts within the Navajo Reservation, quantities of these stones may be seen. All of them so far as known have been picked up by Navajos, who dispose of them to traders and to the few other whites who have visited the little-known Navajo country. The garnets occur in remarkable abundance. Most of the stones have little value as gem material either because of size or of imperfections;[1] selected specimens, however, possess great beauty and are much in demand.

A mineralogical examination indicates that the "Arizona ruby" is a pyrope garnet. Its characteristic color is that of Burgundy wine, but lighter shades are frequently found and dark red stones are not uncommon. So far as known this field is the only producer of pyrope within the United States and is capable of supplying the jewelry trade for many years to come.

Distribution.

Pyrope in small quantity is found in alluvium at Fort Defiance, at Buell Park, and at several other localities in connection with basic dikes and necks, as inclusions in igneous rock and in volcanic agglomerate. Garnet deposits of sufficient extent to justify commercial exploitation occur at three localities which for purposes of description have been named the Mule Ear, Garnet Ridge, and Moses Rock garnet fields, as shown on the accompanying map (Fig. 16). Within these fields the surface is strewn with glistening red pyrope associated with a unique conglomerate composed of boulders, most of which are of types not found elsewhere within the Colorado Plateau Province.

At Mule Ear garnets are relatively rare and the Indians spend

[1] For a description of these garnets, see D. B. Sterrett, "Mineral Resources of the United States," 1908, Pt. II., Nonmetallic Products, pp. 823–839.

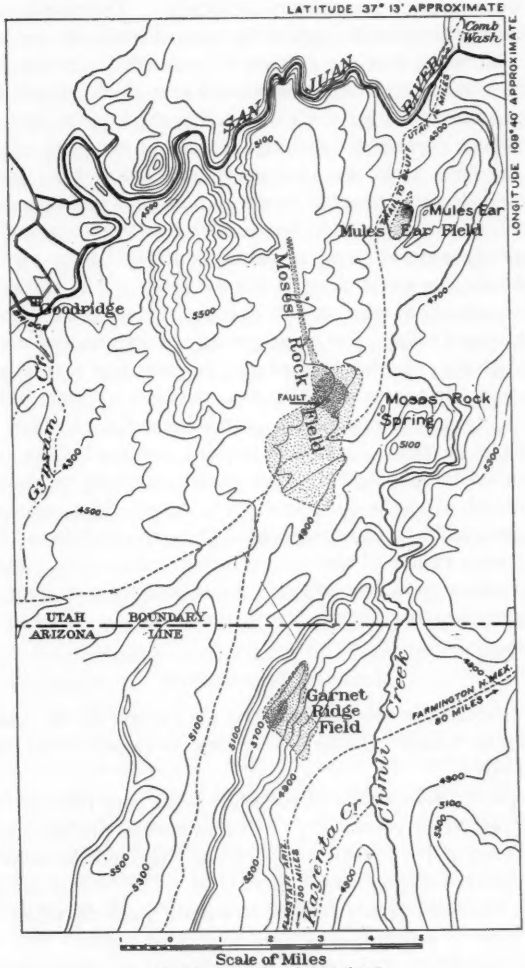
LATITUDE 37° 13' APPROXIMATE
LONGITUDE 109° 40' APPROXIMATE
Comb Wash
SAN JUAN RIVER
Mules Ear
Mules Ear Field
Woodridge
Moses Rock Field
FAULT
Moses Rock Spring
Gypsum Ck.
UTAH
ARIZONA
BOUNDARY LINE
Garnet Ridge Field
Chinle Creek
Kazenta Cr.
FARMINGTON, N. MEX. 90 MILES
FLAGSTAFF, ARIZ. 180 MILES
Scale of Miles
Contour interval 200 feet

FIG. 16.

little time searching for gems in this locality. The talus is coarse, and the fragments of Triassic shale form such a large part of the superficial debris that the garnets are concealed. In the Moses Rock locality the surface is continuously swept by southwest winds and the garnet bearing "drift" as well as the ledge is alternately covered and exposed by shifting dunes. Garnets are gathered from the sand, from the wind-swept ledges, and from anthills, and new collecting ground is furnished with each new distribution of windborne sediment. At Garnet Ridge wide expanses of bare rock are exposed and strong winds and storm-fed sheets of water keep the surface swept clean of fine materials. The garnets are therefore plainly in view, strewn over the surface or accumulated in pockets and riffles. The great quantity of garnets and the ease with which they may be obtained give this area first rank as a collecting field. In selected localities five minutes is sufficient time for gathering from a natural riffle a quart of material of which fully one half is garnets. From two anthills examined there might have been obtained a bushel of fragments consisting of about 40 per cent. of wind-scoured garnets and garnet chips, associated with quartz pebbles, cleavage pieces of feldspar, peridots and fragments from a variety of igneous and metamorphic rocks. Masses of solid garnet up to four inches in diameter were seen and irregular aggregates one eighth to one half inch in diameter are common.

Mode of Occurrence.

Aside from their commercial value the garnets of the Navajo Reservation possess considerable interest as regards their mode of occurrence.

Geologic Rlations.—The three garnet fields have the following geologic features in common: (1) The sedimentary strata present are of Permian (?), Triassic and Jurassic age and are involved in the eastward-dipping Comb Monocline. (2) Within an area of a few thousand square feet the strata are much disturbed and lie as a mass of broken blocks tilted at various angles. (3) The surface is mantled with "drift" and masses of the same material are found lying among the broken sedimentary blocks or plastered

against their sides. (4) The garnet-bearing "drift" of a high central area has been spread by running water over the surrounding slopes. (5) The conglomerate or gravel constituting the "drift" is nearly identical in composition at all localities, and includes the following materials: biotite granite, granite porphyry, porphyritic biotite granite gneiss, garnetiferous diorite, garnetiferous diorite gneiss, red sandstone, gray sandstone, red shale, fossiliferous limestone of Pennsylvanian age, slate, muscovite schist, chlorite schist, quartzite, augitite, minette, hornstone, serpentine, chalcedony, and jasper. Pebbles and boulders of these materials range in size from a fraction of an inch to four or five feet in diameter. In anthills fragmentary crystals of diopside, tremolite, tremolite asbestos, epidot, peridot, feldspar with moonstone lustre, and red quartz are associated with the garnets. (6) With the exception of certain sandstone and shale fragments the pebbles and boulders forming the conglomerate are foreigners. The nearest outcrop of Pennsylvanian limestone is in the canyon of the San Juan River, and a stretch of over 100 miles of sand and rock must be traversed before gneiss, schist, slates and garnet-bearing dioritic rocks are found in position.

Source of the Garnet-Bearing Drift.—The unusual stratigraphic and structural relations of the garnet-bearing drift and its unique composition render a determination of its source a subject worthy of investigation.

Sterrett, who visited the Garnet Ridge field in 1908, states that "The source of the garnets over the mesa country is in a stratum of coarse, unconsolidated drift or gravel that rests on the more elevated part of the sandstone in the country to the northwest of the area examined." The drift was considered as probably of glacial origin, "of greater age than the glacial deposits of the San Francisco Mountains."[2] The Mule Ear field was mapped by Woodruff in the course of a detailed examination of the San Juan Oil Field. This author reports that the area in which the garnets occur is "covered by debris which is believed to be of

[2] *Loc. cit.*, p. 25.

glacial origin" and which "rests in an old channel carved in the Moencopie and Dolores formations."[3]

That Pleistocene glaciation might have occurred in the arid southwest in latitude 37° and at an elevation of 4,800 feet is a matter for comment, and since, as correctly stated by Sterrett, the "drift" is interbedded with sandstone, the probability of demonstrating Mesozoic glaciation becomes a matter of scientific interest. Moreover glacial deposits are not known elsewhere to serve as a matrix for garnets of economic importance.

During the past field season an opportunity was afforded to study these deposits in the hope of demonstrating Mesozoic glaciation in Arizona.[4] The result of this investigation indicates that volcanism rather than glaciation is responsible for the garnet-bearing gravels. In the Mule Ear field it was found that narrow interrupted bands of yellow-green soil could be traced for distances of 10 to 50 feet and that at least one of these bands traverses the strata vertically from the bottom to the top of a ridge mantled with garnet-bearing "drift." In shape and position these soil stripes have the appearance of decomposed intrusive masses, and excavation proved them to be dikes with well defined borders. The material composing the dikes and adjoining masses of irregular shape is identical in composition with the superficial drift. In the Moses Rock area a decomposed dike may be traced from the north, for a distance of about two miles, into the field where conglomerate is most abundant. The dike is a pudding of limestone and igneous rocks, schists and slates, with a weak cement of basic igneous material. A thoroughly decomposed dike of conglomerate traversing Garnet Ridge is continued as a bed or sheet of rock containing the materials of the drift and occupying a position between essentially unaltered sediments. The field evidence thus points to igneous intrusions as the source of the materials constituting the drift.

The intrusions at these three localities are, however, abnormal in three respects: (1) Unmodified igneous rock of a definite type

[3] U. S. Geol. Survey, Bull. 471, 1912, pp. 86–87.

[4] Financial assistance from the Dana Fund of Yale University is gratefully acknowledged.

constitutes a very small part of the dikes examined; foreign materials which would ordinarily be classed as inclusions make up 50 to 80 per cent. of the intrusive masses. In fact the rock is a conglomerate of granite, gneiss, schist, quartzite, limestone, sandstone and shale, with smaller amounts of other materials, for which olivine diabase (?) and minette form the cement. (2) At Mule Ear and Moses Rock many fragments, including most of the larger blocks lying on the surface, are angular and within the dikes themselves unweathered angular fragments are found. Rounded and subangular boulders are, however, fairly abundant and at Garnet Ridge most of the boulders revealed by excavation are rounded or sub-angular, well worn, smoothed or even polished; and in a few instances, grooved and striated. This material shows little indication of modification by igneous action and could be duplicated in the stratified drift and till of glaciated regions. (3) Some of the boulders and blocks have greater width than the dikes and in the areas of disturbed strata at each locality the conglomerate occurs in capricious fashion as masses, lenses, and stringers, and as patches plastered on sedimentary blocks. The impression is gained that much of the material cannot be assigned to dikes with definite orientation, but that the mass as a whole was forced upward, being again and again broken and rearranged. The features observed in the field are accounted for on the assumption that their disorganized intrusions represent volcanic necks or dikes.

Source of the Garnets.—On examining the country rock and the boulders in the drift, it was found that the sedimentary strata are not garnet-bearing, and that garnets imbedded in the igneous paste are rare. Pebbles of garnetiferous gneiss, however, are included within the dikes and the superficial drift. Rock fragments rich in garnets are surpassed in number only by boulders of granite and granite-gneiss. Masses of diorite-gneiss and of schist in which garnet ranks second to feldspar in quantity are common and in some specimens irregularly shaped garnet aggregates attain a diameter of one half to two inches. The garnets included in the boulders are identical with the pyrope widely scattered over the surface.

There is little room for doubt that the garnets of the Mule Ear, Moses Rock and Garnet Ridge fields find their source in boulders and pebbles of garnetiferous gneiss and schist which have been brought to the surface from an unknown depth and from an unrecognized formation by the peculiar intrusions described above.

It is of interest to note that the Bohemian garnets,[5] the "Elie rubies" from Scotland,[6] and the "Cape rubies" from South Africa[7] occur in conglomerate or breccia associated with volcanic intrusions or necks of peridotite rock, closely similar in composition to the intrusives of the Navajo Reservation.

[5] Oehmichen, "Die Bohmischen Granatlagerstatten," etc., *Zeit. f. prak. Geol.*, Vol. VIII., 1900, pp. 1–16.

[6] Heddle, "Mineralogy of Scotland," Vol. II., 1901, p. 48.

[7] Hatch and Corstorphine, "The Geology of South Africa."

ORE GENESIS AND CONTACT METAMORPHISM AT THE LONG LAKE ZINC MINE, ONTARIO.

W. L. Uglow.

I. INTRODUCTION.

In view of the recent discussion in the columns of Economic Geology on the subject of the genesis of contact metamorphic zones, a brief account of the occurrence of zinc ore at the Long Lake Zinc Mine may prove interesting. No attempt is made at a complete and detailed petrographical description as all the evidence cited is the result of field observations. The suggestion is made that the metamorphic zone, including the ores, may be the result of the process of recrystallization, under conditions of high temperature and pressure, of materials previously existing within the limestone.

It is hoped that the discussion may draw attention to the possibilities of the district as a producer of zinc and lead ores, at a time when the metals are in considerable demand.

II. LOCATION.

The Long Lake Zinc Mine, which is not being worked at the time of writing, is situated in the central part of Frontenac County, Ontario, and about thirty-six miles north-northwest of the city of Kingston. It is about six miles north of the new Lake Shore line of the Canadian Pacific Railway between Montreal and Chicago, and about eight miles west of its junction with the Kingston and Pembroke branch of the same system.

III. GEOLOGY.

The geology of the surrounding district is that of the Pre-Cambrian terrane of Canada, and is typical of its general character as developed in southeastern Ontario. About sixteen miles to

the south is the overlapping edge of the almost undisturbed Palæozoic strata. About twenty-five miles to the west is the classic Hastings area.

The rocks are well exposed, and the succession in its broad features appears to be as follows:

Sandstone : Potsdam (Upper Cambrian)
Unconformity
Granite : Moira (?)
Intrusive contact
Gabbro and diorite gneisses
Intrusive contact
Crystalline limestone
Quartzites
Acidic gneisses
Green schists

The four members of the bracketed group will be spoken of in this paper as a complex for the reason that their mutual relations within this district have not yet been worked out. Only the crystalline limestone occurs in the immediate neighborhood of the mine.

Crystalline Limestone.—The oldest rocks in the mine area are white coarsely crystalline limestones, which strike about N. 20° E. and dip from 80° to 90° south. They occur in elongated strips seldom more than a few hundred feet in width, parallel to the general trend of the complex of quartzites, gneisses and schists. It is probable that parts of this complex are to be correlated with the Laurentian and other parts with the Grenville series of Miller and Knight.[1]

Gabbro and Diorite Gneisses.—Associated with the complex, but clearly intrusive into it, is a series of gabbros and diorites, usually somewhat foliated. The foliation of these gneisses is parallel to the general northeasterly trend of the members of the complex. Numerous dikes of gabbro and other basic types in-

[1] W. G. Miller and C. W. Knight, "The Pre-Cambrian Geology of Southeastern Ontario," Ann. Rept. Bureau of Mines, Toronto, Vol. XXII., Part II., 1914.

trude the crystalline limestone, as shown in diamond drill cores, but whether or not they are offshoots from the gabbro or basic differentiates from the later granite was not determined.

Granite.—Cutting all the above mentioned rocks and underlying great stretches of country to the north and south, is a massive, coarse-grained granite, apparently fresh and of a rich pink color. It consists of feldspar (variety not determined) and quartz with minor amounts of biotite and hornblende. As far as known, this granite cuts across the crystalline limestone and ore bodies only in dikes and not as large intrusive masses. Dikes of aplite from this parent source intersect the gabbro dikes within the limestone area, and together with the associated pegmatites constitute the youngest rocks of the Pre-Cambrian area. Lithologically and texturally this granite resembles closely the Moira[2] and Lorrain[3] granites of Miller and Knight, and the Algoman granite of Lawson.[4] The immediate associations, however, only warrant its designation as Post-Archæan. It has apparently not been succeeded by any period of noticeable deformation.

IV. DEVELOPMENT AND EXPLORATION.

The mine, which had been closed down for about seven years, was unwatered during the winter of 1914–1915; and a thorough examination of the underground workings by the writer afforded a good opportunity for studying the problem in hand. The following development work had been done on the property: (*a*) five shafts on the ore body, varying from 60 to 125 feet in depth, (*b*) about 350 feet of drifting, mainly on ore, (*c*) three open cuts, and (*d*) 25 pits and trenches varying in depth from 3 to 30 feet. As a valuable supplement to the data collected from these

[2] W. G. Miller and C. W. Knight, "The Pre-Cambrian Geology of Southeastern Ontario," Ann. Rept. Bureau of Mines, Toronto, Vol. XXII., Part II., 1914, p. 50.

[3] W. G. Miller, "The Cobalt-Nickel Arsenides, and Silver Deposits of Temiskaming," 19th Ann. Rept. Bureau of Mines, Toronto, 4th ed., Part II., 1910.

[4] A. C. Lawson, "The Archæan Geology of Rainy Lake Restudied," Geological Survey of Canada, Memoir 40, 1913, p. 4.

PLAN
VERTICAL SECTION
LONG LAKE ZINC MINE
Long Lake, Saskatchewan
LEGEND
SCALE
NOTE

FIG. 17.

sources, there are the records of 1,000 feet of diamond drilling, distributed in a series of shallow holes crossing the ore horizons.

V. OCCURRENCE AND CHARACTER OF THE ORE.

1. *Size and Shape of the "Lenses."*

The ore consists chiefly of zinc blende (black jack variety) with varying amounts of the sulphides of iron, and small amounts of galena. It occurs in a series of thickened and flattened "lenses" distributed in at least three almost vertical horizons parallel to the banding of one of the elongated masses of crystalline limestone. The limestone may be followed for several miles east and west, by intermittent exposures, and it usually carries traces at least of zinc blende.

There are three main ore horizons, as shown on the accompanying map. The two chief ones lie within the limestone band, at distances averaging about 80 and 200 feet south of the northern contact. Another horizon occurs within the limestone along the northern contact, as shown in some trenches on the eastern half of the map. No mining has been done on this horizon. In addition to these main localities, thin lenses and disseminations of zinc blende may be seen at other horizons within the limestone.

The so-called "lenses" vary considerably in size and shape. In general, they are approximately circular, but they vary in size from one with a diameter of about 100 feet, and a maximum thickness of from one to eleven feet, to one with a diameter of ten feet and a maximum thickness of three feet. All variations between these sizes and shapes may occur. Some of the "lenses" resemble a flattened cigar in shape, and pitch to the east or west down the strike of the enclosing limestone. A constant or gradually decreasing thickness towards the edges is the exception. Each particular body may pinch and swell several times between its center and its circumference. As a general rule, individual "lenses" appear to be entirely separate bodies with no connection between adjacent ones. Exceptionally a small stringer may connect two comparatively large bodies of ore. These connecting

links usually consist of thinly disseminated zinc blende and pyrite along one or two thin bands of limestone and may escape the notice of one not searching for them.

The "lenses" are not bounded by sharp contacts, like fissure fillings. Looked at from a short distance, the transition from ore to limestone seems to be very abrupt. Closer examination, however, shows that the contact is ill-defined, and is usually marked by an intimate intergrowth of grains of sphalerite and crystalline limestone, and that there is nothing to suggest that the blende had been deposited on a previously existing well-defined wall. A "lens" of ore followed along the strike may be seen to give place to the crystalline limestone usually in the same manner as it does across the formation. That is to say, there is no evidence of a crack or fissure, filled or unfilled, which may have afforded a means of access for the ore materials. A sufficient number of these "lenses" have been examined around their entire periphery to afford a reasonable proof for the statement that such fissures or means of access do not at present exist. In some of the leaner parts of the deposit, considerable disseminated zinc blende is found in the limestone, and careful inspection shows that there are all gradations between the disseminated type and the closely packed massive type.

2. *Mineral Association and Paragenesis.*

As is briefly stated above, the ore is chiefly zinc blende of a dark chocolate brown color, with minor amounts of pyrite, galena, pyrrhotite, and chalcopyrite. The more coarse-grained phases of the ore are composed almost exclusively of black jack or ferriferous blende, while the medium and fine-grained phases are usually somewhat intimate mixtures of blende, with varying amounts of galena and the sulphides of iron.

In places, as far as known chiefly near the northern contact of the limestone, galena is sporadically abundant. Some large masses of pure galena are reported to have been taken out of the workings in the past, but nothing of this sort was seen during the recent examination and exploration. The usual occurrence of

galena is in small grains intimately associated with the zinc blende. Frequently small clusters of cubical galena may be seen solidly embedded in the more massive zinc ore.

Pyrite and pyrrhotite, with small amounts of chalcopyrite, occur at some places quite abundantly, in the medium and fine-grained types of ore in close association with the blende. The outside edges and extensions of the ore "lenses" and the horizons between successive "lenses" are often rich in sulphides of iron, although barren of galena and blende.

In those phases of the deposit where the ore is fine-grained, the general rule is that grains of the gangue minerals—chiefly calcite, greenish diopside and quartz—are pretty intimately mixed with the ore minerals. Sometimes, however, these minerals occur in small bunches or clusters within the apparently solid mixed ore. In general there is no difference in textural characteristics between ore and gangue minerals.

Apart from the ore horizons, diopside and quartz are not abundant. Around the edges of the ore "lenses" and especially along a general horizon in which ore occurs, localities rich in diopside are common. It is not unusual to find an outward transition in the plane of the banding of the limestone from zinc ore to a zone of iron sulphide disseminations and then finally to a zone of mixed calcite and diopside grains.

Very little can be said as to paragenesis. The latest period of recrystallization under conditions of anamorphism has apparently obscured all evidence of the time relations of the constituent minerals. The intimate association and the textural characteristics of grains of both ore minerals and gangue point to their simultaneous formation, at least in their present form. None of the minerals occurs in veins cutting any other, and disseminated and massive types are the rule. What the time relation of the minerals was before the recrystallization is a matter of conjecture, but some light may be thrown upon it by the suggestion made in the section on "Contact metamorphism" that this ore body may represent in an anamorphosed form a type resembling the zinc deposits of the Upper Mississippi Valley.

Secondary enrichment in the present cycle has been inconsiderable. Fresh unoxidized glaciated surfaces are the general rule. Occasionally the oxidized zone is two or three feet deep, where the ground is somewhat broken and the surface is unprotected by drift. Small amounts of secondary zinc and iron sulphides may be seen in vugs to a depth of at least 100 feet.

3. *The Ore.*

A twenty-pound sample of the ore taken from the various outcrops and dumps by the writer gave the assay in column (*A*). Although the sample was a very rough one and was chiefly for the purpose of determining the amounts of deleterious constituents, it will give an approximate idea of the quality of the ore. Column (*b*) gives the assay of a hand-jigged concentrate from a fifteen-pound sample of Long Lake ore. For the sake of comparison the following analysis of a 40 per cent. zinc concentrate from southwestern Wisconsin is given in column (*C*).

	(*A*), Per Cent.	(*B*), Per Cent.	(*C*), Per Cent.
Zinc	35.40	40.00	40.00
Iron	8.60	9.40	14.05
Lead	0.75	0.50	0.30
Copper	....	....	....
Cadmium	....	....	....
Arsenic	....	....	....
Silver	1.05 oz.	....	Small amount not determined
Insoluble	17.00	5.00	5.00

The importance of the similarity of the Wisconsin and Long Lake ore analyses is due to the fact that the Wisconsin variety represents an ore that has been deposited in a series of limestones by descending waters without the aid of igneous activity. This feature is discussed in a later section.

Although as a producing mine the Long Lake property would be largely a concentrating proposition, considerable crude ore might be obtained by hand sorting that would assay 50 per cent. zinc. It is not likely, however, that a concentrate higher than 45 per cent. in zinc could be made from the remainder.

4. *Textural Characteristics.*

The ore varies from fine to very coarse-grained, apparently depending on its mineral association. In certain parts of the deposit the ore is almost exclusively zinc blende, the only impurity being the iron chemically combined in the zinc blende molecules. In such cases the constituent grains frequently attain a diameter of two or three inches, and large glistening cleavage surfaces may be seen.

There are all gradations from this coarse-grained pure type to the other extreme—that of an intimate mixture of grains of zinc blende, pyrite, pyrrhotite, galena and chalcopyrite. The grain in this variety is usually fine, a probable average size being about 0.06 inch.

In the fine-grained variety, as contrasted with the coarse-grained, the grains of the metallic constituents are not only mixed intimately with each other, but also with grains of calcite, quartz and lime silicates, all of a remarkable evenness of fabric.

Both varieties of the ore grade at the edge through a narrow disseminated phase into the enclosing crystalline limestone. As a general rule, the ore grains, especially in the complex type, are slightly smaller than the grains of the enclosing limestone. All degrees of dissemination occur. In a number of places on the glaciated surface of an exposure of the limestone, a slightly brown streak, when examined closely, will reveal a few grains of zinc blende scattered between the grains of calcite. In what may be called the disseminated phase in which ore and limestone grains are mixed in about equal proportions, the association of metallics and non-metallics is very intimate. The grains of sphalerite tend toward a crystal form, usually exhibiting a drop-like shape, while pyrite and galena are generally cubic.

The grains of the enclosing limestone vary from a few hundredths of an inch to fifteen inches in diameter. The associated silicates are usually not in such large grains.

All the textural evidence points to a simultaneous crystallization of ore, limestone and silicates.

EXPLANATION OF PLATE XIII.

FIG. 1. Cluster of secondary silicate minerals in the Long Lake limestone. Dark bands contain grains of pyrite, zinc blende and diopside.

FIG. 2. General view of property from east.

FIG. 3. Grain of calcite in crystalline limestone, more than 1 foot in diameter.

FIG. 4. Old mill dumps from the southeast.

FIG. 1.

FIG. 2.

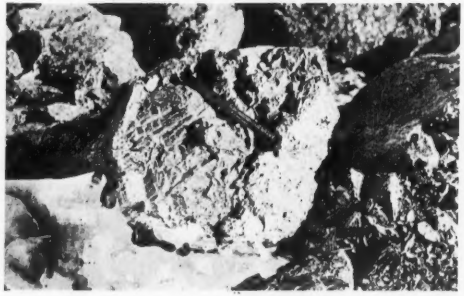

FIG. 3.

FIG. 4.

5. *Relation to Intrusives.*

In so far as their relation to intrusive masses is concerned the ore and the limestone may be considered as a unit. In their present recrystallized condition they are of simultaneous formation. Large masses of the gabbro and granite do not seem to cut across the limestone band, at least in the neighborhood of the mine, and consequently not across the ore formation. They, however, appear to be in intrusive contact with the limestone along both of its edges. Numerous dikes of gabbro, diorite, granite, aplite and pegmatite cut in all directions across the ore horizons, and in some instances they intersect lenses of ore, slightly offsetting parts of them. These dikes have not been observed over ten feet in width.

The ore, therefore, was existent in its present form before the periods of dike intrusion. Its relation to the gabbro invasion is, however, not quite so clear.

VI. CONTACT METAMORPHISM AND ORE GENESIS.

1. *The Long Lake Limestone.*

Owing to the general anamorphism of the rock series with which this limestone is associated it is impossible to determine its original character and composition. Other Pre-Cambrian limestones occur in neighboring districts, as for example the Hastings limestone, and these are usually bluish-gray, finely-crystalline, thinly-bedded rocks, generally magnesian and siliceous. These of course have undergone a certain degree of anamorphism, but it has not been severe enough to obliterate the original stratification. It seems reasonable that, before the period of contact metamorphism caused by the granitic invasion, the Long Lake limestone may have resembled closely in character the Hastings limestone. In its present form, however, the Long Lake limestone is a white coarsely crystalline variety, only exhibiting traces that suggest original bedding.

Near the center of the band, that is at the greatest distance from the intrusive, the Long Lake limestone is rather fine-grained

(1–2 mm.) although still white and crystalline. This apparently represents its least altered phase in the immediate vicinity. Near the granite and gabbro contacts, however, the grain of the limestone very appreciably increases in size. Single grains five or six inches in diameter are by no means uncommon, and in one instance an individual with a diameter of fifteen inches was found.

Generally a rough banding is observable in the limestone. As indicated above this may be a remnant of the original bedding, which is very pronounced in the blue-gray less altered Hastings limestones, for example. The thickness of the so-called bands in the Long Lake limestone corresponds very closely to that of the layers in the Hastings formation, both being from one quarter inch to one inch in thickness in general. This banding in the Long Lake limestone is not so noticeable on close inspection as it is at a distance of about eight feet. The divisional plane between two bands is not a smooth one as in the Hastings limestone, but is a serrated surface due to the projecting angles and edges of a band of coarse grains, the re-entrants of which are filled with smaller grains of an adjacent fine-grained band.

Throughout the limestone formation, accessory minerals, such as graphite, white or yellowish mica (phlogopite) and chondrodite are sometimes abundant, and these are linearly distributed in such a way as to emphasize the banded structure and to give the rock an almost gneissic appearance. Minerals of a commonly accepted pneumatolytic origin are noticeably absent, and there is no evidence that any of the silicate minerals have been formed by agencies other than heat and pressure, while the rock was undergoing a deformation in the zone of flowage. Identically the same association of secondary minerals occurs throughout most of the crystalline limestones of Ontario and Quebec, where their presence is most reasonably explained as due to the action of regional rather than contact metamorphism.

2. *The Ore.*

There is nothing in the field evidence to suggest that the ore "lenses" were formed by agencies other than those which pro-

duced the secondary silicate minerals and the coarse crystallization of the limestone. The various features which suggest recrystallization rather than infiltration as the origin of the ore in its present form are summarized below. Although almost any one of these criteria taken by itself may not be determinative, all of them taken together seem to support the hypothesis that the constituents of the ore lenses and of the secondary silicates were inherent within the limestone formation, at least during the cycle previous to the deformation and recrystallization that left them in their present form.

(i) The ore "lenses" are distributed through the limestone in definite horizons, one along the northern contact of the limestone, and the others between it and the center of the formation. It may be that these horizons are the anamorphosed representatives of certain horizons of the limestone, which, previous to the metamorphism, were rich in the sulphides of zinc, iron and lead.

(ii) Within each of these ore horizons the ore is strung out either in a series of "lenses" or bedded masses, or in disseminated streaks. There is every gradation between the two extremes.

(iii) There is no definite line of demarcation between ore and limestone, and a gradual transition is the universal rule.

(iv) A mineralogical and chemical analysis of the ore shows no mineral or constituent of pneumatolytic origin, and none that might not have been readily formed under conditions of high temperature and pressure by the recrystallization of materials previously contained in the limestone.

(v) Dikes of gabbro and granite cut the ore "lenses," showing that the latter were solidified and in place before the intrusions.

(vi) Medium-grained pegmatites which are not uncommon were searched for sphalerite and galena without positive results.

(vii) No fractures, filled or unfilled, have been observed that might have afforded a means of introduction for the ore minerals.

(viii) The ores occur near the northern contact of the limestone, where the coarseness of grain shows the anamorphism to have been greatest. Under this condition better opportunity would

have been afforded for the ore minerals to segregate into masses. The southern border of the limestone has so far been very inadequately explored.

(ix) The analysis of the ore resembles closely the average analysis of Wisconsin zinc ores, of similar grade, in the origin of which igneous activity is believed to have played no part. In the case of these deposits also, the ores occur in definite horizons within the sedimentary series.

(x) Iron sulphides occur very commonly around the boundaries of ore "lenses," and a pyrite zone frequently indicates the edge of individual ore bodies. The same feature is very noticeable in zinc ore deposits of sedimentary origin, notably those of the Upper Mississippi Valley.[5]

(xi) In no case were veins or stringers of ore seen to cut either the gabbro or granite as might be expected, if the ores were infiltrations from the intrusives.

(xii) The occurrence of lime silicates in the ore horizons, and especially in the vicinity of the ore bodies, suggests that they might be the anamorphosed product of flint horizons in limestone formations, with which sedimentary zinc and lead ores are frequently associated.

All the above mentioned criteria suggest, therefore, that the ore minerals existed in some form in the Long Lake limestone before the granite intrusion. Some of the evidence indicates that they might have been present in the limestone in a form similar to that in which a great many sedimentary ores of zinc and lead occur —either as original or secondarily deposited sulphides having no genetic relation to igneous action. If such be the case, therefore, the horizontal extent of such sedimentary unmetamorphosed ores would now be represented in the Long Lake deposit by vertical extent, and since the sedimentary ore horizons are usually flat and tabular in shape with greatest lateral extent, considerable depth might be expected for the ores of Long Lake.

[5] H. F. Bain, "Zinc and Lead Deposits of the Upper Mississippi Valley," U. S. G. S. Bull. 294, 1906. G. H. Cox, "The Origin of the Lead and Zinc Ores of the Upper Mississippi Valley District," ECON. GEOL., VI., No. 5, 1911, p. 427.

VII. CONCLUSION.

From the evidence summarized above, it seems reasonable to believe that the ore and enclosing limestone represent an anamorphosed phase of a previously existing deposit, similar, perhaps, in many respects to some of the zinc deposits of the Upper Mississippi Valley, for instance. There is no evidence that the great granitic invasion of that part of Ontario, a part of which is in close contact with the Long Lake limestone, added any constituents either in the way of ore or gangue to the deposit, but there is no doubt that it affected considerably its structure and texture. The heat and pressure which must necessarily have been an accompaniment of the intrusion, probably brought the surrounding rocks into the zone of flowage, and caused the coarse crystallization of the limestone, the segregation of ore minerals, and the probable expulsion of carbon dioxide from the limestone, thus allowing for the formation of the lime silicates.

It is offered as a suggestion that this deposit may afford an example of an ore body formed strictly by the metamorphic, as distinct from the metasomatic phase of contact metamorphism. In other words, it is suggested that the mineral constituents were simply segregated, when the formations were subjected to conditions of rock flowage, and were not introduced into the limestone as an impregnation or replacement accompanying the igneous intrusion.

THE OCCURRENCE OF PETROLEUM IN THE PHILIPPINES.[1]

WALLACE E. PRATT.

INTRODUCTION.

The existence of petroleum in the Philippines became known during the latter years of the Spanish regime. The Spanish geologist, Abella,[2] mentions the occurrence of petroleum on the islands of Leyte and Cebu and of inflammable gas on the island of Panay, but records very little information beyond the situations of each of the seepages. The petroleum of the peninsular part of Tayabas Province in southern Luzon, which has attracted a great deal of attention from Americans, seems not to have been known to the Spaniards. A small flow of inflammable gas in the southwestern part of the island of Mindoro and traces of petroleum in northwestern Pangasinan, west-central Luzon, have also been discovered within the period of American dominion in the Philippines. While there has been no real exploration of the prospective fields by drilling and, consequently, there is no assurance that a commercial production will be developed, preliminary examinations of the most promising regions have revealed conditions that afford possibilities.[3]

[1] Published by permission of the Director, Bureau of Science, Manila.

[2] Abella y Casariego, Enrique, "Descripcion fisica, geologica y minera en bosquejo de la Isla de Panay," Chofre y Cia, Manila (1890), 67.

[3] More detailed descriptions with maps and geologic sections will be found in the following references: Pratt, Wallace E., and Smith, Warren D., "The Geology and Petroleum Resources of the Southern Part of Bondoc Peninsula, Tayabas Province, Philippines," *Phil. Jour. Sci.*, Bur. Sci., Manila, Sec. A (1913), *5*, 301–376; Pratt, Wallace E., "The Occurrence of Petroleum in Cebu," *Idem.*, Sec. A (1915), *4*; Pratt, Wallace E., "Petroleum and Residual Hydrocarbons in Leyte," *Idem.*, Sec. A (1915), *4*.

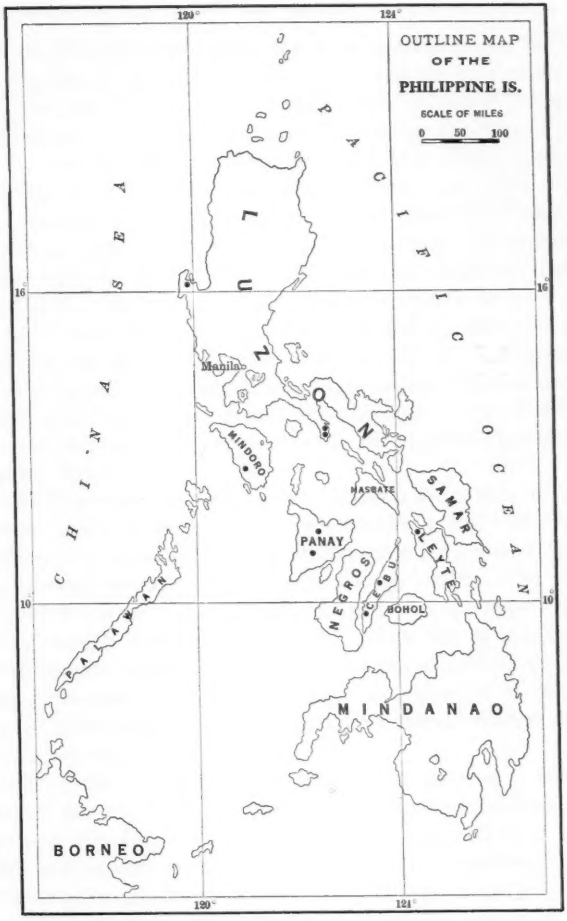
OUTLINE MAP
OF THE
PHILIPPINE IS.
SCALE OF MILES
0 50 100
120°
124°
16°
10°
SEA
LUZON
PACIFIC
OCEAN
CHINA
Manila
MINDORO
MASBATE
SAMAR
LEYTE
PANAY
NEGROS
CEBU
BOHOL
PALAWAN
MINDANAO
BORNEO

FIG. 18.

GEOLOGY.

Stratigraphy.

In the Philippines petroleum occurs as small seepages, usually accompanied by inflammable gas, along outcrops of a series of shale beds of Miocene age. In the typical Philippine sedimentary column no rocks older than the Tertiary are known certainly; very limited exposures of cherts and slates resulting, probably from the metamorphism of fine-grained tuffs, have been found at several places and have been tentatively classed by Smith[4] as Jurassic, but it is admitted that they may represent metamorphosed Tertiary beds. At any rate Oligocene fossils are found at the base of the principal sedimentary series. This series is found throughout the Philippines and contributes materially to the aggregate volume of the land mass. Sub-bituminous and lignite coal occurs in the Oligocene and Miocene and is widely distributed in the archipelago although, it may be noted, the usual coal beds are not observed in the important petroleum-bearing regions.

The Oligocene rests unconformably upon a complex of deep-seated, intrusive, effusive, and metamorphic rocks. The basal sedimentary beds are fine, well-cemented conglomerates, grading upward through sandstones into sandy shales. The thickness of this stage is not constant, but so far as observation goes, never exceeds 200 feet. There is a 3-foot bed of coal in the conglomerate which also encloses numerous fragments of silicified, carbonized wood. Judging from the character of the pebbles in it, the conglomerate may have been derived from the complex upon which it lies.

Above the conglomerate-sandstone-shale stage is a heavily-bedded foraminiferal limestone with a maximum thickness of, perhaps, 100 feet. This member, again, is inconstant in thickness and appears even to be lacking in some exposures. It is blue to yellowish-brown in color and, although thoroughly crys-

[4] Smith, Warren D., "Contributions to the Stratigraphy and Fossil Invertebrate Fauna of the Philippine Islands," *Phil. Jour. Sci.*, Sec. *A* (1910), 246.

talline, contains numerous fossil casts. According to Smith[5] this limestone is to be assigned to the Oligocene. *Nummulites niasi* Verb. and *Heterostegina margaritata* Schlumberger are included in the list of species provisionally identified by him in it.

Conformably above this limestone is an extensive succession of shale beds with subordinate sandstone and tuff-sandstone. As many as six coal beds are found in this shale in Cebu. Petroleum occurs in the same member in Leyte, Tayabas, and in parts of Cebu where the coal is either lacking or present only in thin beds. The basal part of the shale is made up of thin regular beds of fine-grained shale, sandy shale, and, more rarely, sandstone or tuff-sandstone. The average thickness of the beds is probably less than four inches, although several of the sandstone strata, while subordinate in number, are often thicker than the fine-grained beds, being as much as two feet. The sandstone appears to contain a large proportion of volcanic tuff and the shale, also, is tuffaceous. Fresh exposures are usually gray to blue in color whereas weathered outcrops present a variegated appearance with predominant yellows and browns. This thin-bedded, lower portion of the shale is about 2,000 feet thick in the prominent coal fields but in the Tayabas petroleum-bearing region its apparent thickness is more than 4,000 feet. The upper part of the shale becomes gradually thick-bedded to massive in structure, consisting, in the coal fields, of about 2,000 feet of shale, sandstone and grit with which the principal coal beds are associated. The shale is still predominant but the sandstone is more abundant than in the lower, thin-bedded part. In the petroleum regions the upper, massive stage of the shale is much thinner than in the coal fields; in Tayabas it is apparently not more than 300 feet thick. The upper massive shales weather into angular fragments with conchoidal faces, whereas the underlying thin-bedded shales are fissile. It will be observed that the total thickness of the shale series is about the same in the coal fields as it is in the areas where petroleum is found, but that the thin-bedded stage has a greater proportional development in the petroleum regions.

[5] *Loc. cit.*, 243.

The upper part of the shale series is the most common source of the surface seepages of petroleum and the underlying thin-bedded shales yield a smaller number of seepages. The upper part of the shale series is of Miocene age, *Vicarya callosa* Jenk. having been found at a number of places in the shale above the principal coal bed.

Above the shale series limestone is encountered at some places but elsewhere clay-tuff and calcareous tuff-sandstone rest directly on the shale, with no intervening limestone. In both cases there appears to be a slight unconformity, or a mechanical discordance at the top of the shale. In the Cebu coal fields a white crystalline limestone of coralline origin overlies the shale, attaining a maximum thickness of 500 feet. Smith[6] has identified a fossil Miocene alga, *Lithothamnium ramosissimum* Reuss, in this limestone. In Tayabas the same fossil was found in sandy limestone just above the shale series.

Unconformably above this limestone, or immediately overlying the shale series where the limestone is lacking, is clay-tuff and tuff-sandstone, increasingly calcareous upward with sandy, coraliferous limestone in the upper part of the stage. In Leyte and in Tayabas these rocks are more than 1,000 feet thick, whereas, in Cebu, different exposures reveal sections in which the thickness varies from 500 to 1,000 feet. The age of the uppermost limestone appears to be Pleistocene while the tuff-sandstone and clay-tuff are thought to be Pliocene or, possibly, Miocene in age. The lower or clay-tuff phase of this series is from 300 to 500 feet thick; it is massive and close-grained, though not indurated, and is relatively impermeable. It is commonly blue to gray in color but where it contains a large proportion of tuff it becomes white. At places the clay-tuff passes laterally into tuff-sandstone but remains generally predominant throughout a zone about 500 feet thick immediately above the shale series. The tuff-sandstone in the clay-tuff stage is also massive; it is cemented with calcium carbonate and the clay tuff is itself calcareous. The tuff-sandstone above the clay-tuff

[6] Smith, Warren D., *loc. cit.*, 243.

stage is bedded, alternate beds being thinner and harder than the intervening layer. There appears to be no difference in the character of the grains in the successive beds and bedding planes are not sharply defined, the rhythmic structure being explained, perhaps, by a periodic increase of the calcium carbonate which binds the grains together. In the upper part of the tuff-sandstone is a sandy coralliferous limestone, 50 to 100 feet in thickness and overlying the tuff-sandstone is another limestone horizon made up principally of coral fragments.

Except in Leyte petroleum does not appear at the surface in the rocks above the shale series, but in Leyte there are many small deposits of petroleum residuals and a single petroleum seepage in the clay-tuff, while one of the upper limestones, also, is impregnated locally with thick black oil.

Recent deposits of raised coral reefs and littoral material are found on different parts of the coasts and subordinate areas of alluvium flank the lower courses of the streams. Modern erosion has cut down to the shale series at many places and, where the beds are closely folded, the shale series has undergone extensive degradation but at no place within the petroleum regions is the underlying basement complex exposed.

Igneous rocks are found at places in the upper part of the shale series. The most common igneous rock is andesite and the outcrops usually appear as small domes. The exteriors of several of the igneous outcrops in Tayabas are brecciated and in some instances the breccias take on the character of volcanic agglomerate in which the matrix is tuffaceous. Breccias of this character are encountered in the upper part of the shale series and along the contact between the shale series and the overlying clay-tuff. The igneous rocks in Tayabas are of subordinate importance as to extent and are confined in distribution to one corner of the petroleum-bearing region. In Leyte small outcrops of andesite are found frequently in the shale series throughout the petroleum region. In Cebu there is a large outcrop of andesite in the vicinity of one of the petroleum seeps and andesitic volcanic agglomerate occurs at the base of the overlying

clay-tuff zone which, in this region, consists essentially of tuff. Some of the andesites appear to be intrusive although the surrounding sedimentary rocks show little evidence of metamorphism; others of the igneous outcrops may represent volcanic flows or agglomerates. One of the andesite domes in Leyte is bordered or veneered in part by a breccia containing fragments of clay-tuff, indicating that the deposition of this rock antedates the period of intrusion. Elsewhere, however, volcanic agglomerate is found at the base of, and is therefore probably older than the clay-tuff.

Traces of petroleum are found in Tayabas within a few feet of one of the igneous outcrops and at one place in Leyte petroleum comes to the surface on the exact contact of the shale series with an apparently intrusive rock. There is a suggestion, also, that the small deposits of residual hydrocarbons in the clay-tuff in Leyte are related in their origin to intrusions.

Structure.

The petroleum-bearing rocks are generally folded so that the beds dip at high angles. The shale series is closely folded while the overlying rocks usually lie at flatter angles although they dip in the same direction. This difference in the angle of dip is the most important evidence of unconformity between the shale series and the clay-tuff. The folds into which the beds are thrown are characterized by sharp broken anticlines and by broader, less acute synclines. The main folds follow the trend of tectonic lines that are prominent in the structure of the archipelago and are reflected in the alignment of the islands. The Tayabas and Leyte regions are upon the same structural line, a conspicuous north-northwest line which coincides farther north with the axis of the Eastern Cordillera of Luzon. Between Tayabas and Leyte the line is marked by raised fault-blocks which form the elongated islands of Burias and Ticao, and by the regular eastern coast of the island of Masbate. The structure in the Cebu fields is governed by the north-northeast line marked by the axis of that island. Subordinate folds in each of the fields cross the main folds approximately at right angles.

Faults are indicated at many places by the stratigraphic relations but direct evidence of faulting is not commonly observed. The softness of the preponderating beds, shale and clay-tuff, undoubtedly tends to close up or heal the fractures and openings resulting from faults. It is fairly certain, however, that faulting and crushing have occurred in the sharp anticlinal folds.

Beyond question the structure has exercised a profound influence over the accumulation of the petroleum. Nine out of twelve of the strongest seepages of petroleum are on the crests or in the limbs adjacent to the crests of well-marked anticlines, and nowhere has a seepage been discovered in a syncline. A deposit of bituminous limestone, or rock asphalt, in Leyte is due apparently to seepage along a fault, and other deposits of petroleum residuals in Leyte probably owe their present distribution to structure resulting from intrusions into the underlying shale series.

Additional data on the geology will be presented in the following descriptions of the various occurrences of petroleum.

OCCURRENCE OF PETROLEUM.

Pangasinan.

For several years the presence of petroleum in northwestern Pangasinan, west-central Luzon, has been the subject of occasional reports. Different investigations, however, have failed to confirm the existence of surface seepages. The rocks exposed at the surface are limestones, calcareous sandstones, and marls which are to be correlated with the upper part of the stratigraphic column as previously described. Nowhere has the underlying shale series been noted at the surface. The structure is a gentle monocline dipping to the westward. The only authentic petroleum sample from Pangasinan was taken from a well drilled at the town of Anda on an outlying island in Lingayen Gulf at the northern end of the possible petroleum field. This well, drilled by the Bureau of Public Works in search of artesian water, encountered salt water with a little petroleum in

organic clay or mud at a depth of 1,200 feet. The sample obtained contained too small a quantity of petroleum to permit the determination of chemical or physical characters. The horizon from which the petroleum came must be near the top of the shale series.

Tayabas.

In the southern part of the peninsular portion of Tayabas which juts off the southern coast of Luzon, in line with the axis of the eastern Cordillera, there are four small petroleum seepages and a half dozen other places where traces of petroleum and inflammable gas are found. These showings are distributed over an area twenty-five miles long by twelve miles wide. The region has attracted much attention from Americans and numerous placer petroleum claims have been filed, only to be allowed to lapse in a majority of cases. The peninsula trends south-southeast from the mainland of Luzon; its lateral coast lines are regular and parallel and the width is maintained constant almost to its southern extremity. The land rises rather abruptly from the sea to extreme elevations of over 1,400 feet, forming a rolling, grass-covered plateau with deeply incised stream lines; timber is encountered along the streams and, also, on the higher ridges.

The stratigraphy conforms closely to the outline already given which is based in part on sections observed in Tayabas. In structure the peninsula may be likened to a collapsed arch; that is, a section at right angles to the peninsular axis reveals a general anticlinal structure with a sharp upward flexure near the center of the peninsula and similar acute anticlines bordering each coast, but intervening between the central and coast anticlines are two broad, gentle synclines. This structure is reflected strongly in the physiography; erosion has progressed most rapidly along the broken crests of the sharp anticlines and valleys mark the anticlinal axes, whereas the beds in the synclines have remained nearly intact. The result is that, while the peninsula has a general anticlinal structure, the highest elevations and the bulk of the land mass are within the synclines, with

prominent coastal ridges marking the seaward-dipping limbs of the lateral anticlines. The anticlines are generally asymmetric and the beds of the shale series are often almost vertical in the steeper limb; the overlying clay-tuff and tuff-sandstone usually do not dip more than 45°. The central and principal anticline has its steeper limb to the east of its axis while the steeper limbs of the coastal anticlines on either side dip toward the coast: that is, the main anticline tends to overturn to the last and the minor anticlines on each side tend to overturn away from the central anticline. There are minor undulations crossing the peninsula approximately at right angles to the general structure lines and the structure as outlined is modified by these cross folds, as well as by a general plunge to the southward throughout the field.

Traces of petroleum are found wherever the massive shale beds of the upper part of the shale series are exposed, and the principal seepages of petroleum occur where erosion has uncovered these beds on the crests of sharp folds. The shale from which the petroleum escapes emits an odor of light oils. It contains numerous small calcareous shells of *Globigerina* which are often greasy and it has been suggested that the origin of the petroleum is related to the decomposition of the original animal matter in these shells. The shale is a compact, fine-grained rock which would afford little opportunity for the accumulation of petroleum, but it is overlain in places by a loose sandstone-conglomerate, twenty feet or more in thickness, which should be porous; at no place has this sandstone been observed to contain petroleum, however.

One of the principal seepages is on the central anticline, while the other three occur at intervals along the sharp arch that parallels the eastern coast line. The petroleum reaches the surface in stream beds and floats away in films and globules on the water. The quantity of petroleum that escapes is small; it is a matter of some difficulty to collect a quart sample at any one of the seepages. Inflammable gas usually accompanies the petroleum, bubbling up through the water, and a spring of salt water occurs near the southernmost seepage on the eastern anticline,

at an elevation of several hundred feet. At the central seepage on the eastern anticline two wells have been drilled, 117 and 300 feet, respectively, in depth. The shallower well, which is only three inches in diameter, and was drilled by hand, encountered small quantities of petroleum and inflammable gas. Possibly a barrel of oil per day could be obtained from this hole. The other well obtained a temporarily strong flow of inflammable gas but was abandoned because of drilling difficulties before it was finished.

Elsewhere in the field films of oil and bubbles of gas appear on the surface of the water when the shale in streams is disturbed with a pick. On the southern limb of a cross fold in the northeastern part of the petroleum region several streams of inflammable gas bubble up spontaneously from the floor of a small stream. A shallow pit, dug in the bedded shale near by, produced a few gallons of petroleum; the shale from which this petroleum comes is about 500 feet below the top of the shale series. Still farther northeast traces of petroleum and inflammable gas were observed within a few feet of an outcrop of intrusive(?) andesite, and in the western part of the region similar indications of petroleum are to be observed along the coastal anticline.

An analysis of the petroleum from Tayabas appears in Table I.

Mindoro.

No petroleum has been found in Mindoro but inflammable gas issues with a continuous flow from a vent in steeply dipping tuff beds in the southwestern part of that island. An idea of the quantity of gas that escapes can be gained from the statement of men who have hunted in that vicinity that the flow has been conducted through small pipes to be used for cooking purposes. The tuff beds from which the gas comes have not been correlated with other geologic sections, but it is presumed that they lie above the shale series.

Panay.

Inflammable gas and traces of petroleum are reported to have been found in shale at two places in Panay. One of the reported flows is near the center of the island in a steeply dipping monocline on the western flank of the cordillera, while the other flow is reported from a point farther north in a region of which little is known geologically. A well was drilled for artesian water at the town of Janiuay, two miles east of the southern gas seepage, and at a depth of 1,800 feet this well encountered salt water, charged with inflammable gas. Both gas and water have flowed by heads through a period of two years, the well having been abandoned, and tiny films of oil appear on the surface of the water. In this case, again, it is not possible to determine from what stratigraphic position the showings were obtained. The well is situated in an alluvium-filled structural valley and the drill cuttings throughout appear to represent alluvial material, although the depth attained should be sufficient to penetrate the underlying sedimentaries.

Cebu.

Petroleum is found in shale near the towns of Toledo and Alegria, thirty-five miles apart, on the western coast of Cebu. At Toledo two wells were drilled in the year 1896, one of which is said to have reached a depth of 1,100 feet; no record of the drilling is available. Each of the wells yields a little petroleum today, even though they are partly filled with debris, and a quantity of oil sufficient for an engine test was recently secured from one of them.

The wells at Toledo and the adjacent seepage are situated upon the outcrop of sandy bedded shales which dip northwest at angles of 45° or more and form a monocline flanking the cordillera of Cebu. The shales are overlain about 200 feet above the position of the wells by fine-grained, white tuff which is to be correlated with the clay-tuff of the typical geologic column. The tuff is about 300 feet thick and is overlain in turn by sandy,

coralline limestone of, possibly, equal thickness. A prominent hill about one half mile to the southwest of the wells, along the strike of the beds, consists of andesite and is taken to represent an intrusion, although it may be the edge of an interbedded flow. Stratigraphically below the position of the wells are sandstone, fine conglomerate, sandy shale, limestone, shale, sandstone, and, at the base of the series, Oligocene limestone resting upon the complex of igneous and metamorphic rocks which forms the cordillera. Shale and sandstone make up most of this series, the total thickness of which is at least 4,000 feet.

The petroleum at Alegria comes from steeply-dipping beds of sandy blue shale in the crest of a sharp anticline which parallels the adjacent coast. No exploitation has been attempted but a small quantity of petroleum oozes from the wall of a creek. The beds from which it escapes cannot be more than a few hundred feet stratigraphically below the upper coralline limestones which are to be seen on either limb of the fold, although they have been removed from the crest over a width of about 1,500 feet. The shale at the seep is a part of the regular shale series, however, and it appears, therefore, that the usual clay-tuff and tuff-sandstone are partly replaced by limestone. Two miles to the south of the seepage and along the line of the anticlinal axis, there is a small exposure of andesite and a spring of hot water.

An analysis of the Cebu petroleum appears in Table I.

Leyte.

Petroleum and solid and viscuous residues from petroleum are found near the western coast of Leyte, toward the northern end of the island. The rocks in which these deposits are found form a peninsula which extends to the north-northwest from the main part of the island, but most of the outcrops are south of a line across the base of the peninsula. The town of Villaba is near the principal deposits. The field as at present delimited extends only about two miles inland and includes low broken country. A number of outcrops of solid petroleum residues are found near the base of a prominent escarpment which trends northwest and

forms the western boundary of the northern part of the field. This escarpment rises more than 1,000 feet above sea level and in it only the beds that lie stratigraphically above the shale series are exposed. The shale series appears in its usual character and relations in the southern part of the field, however. Both the shale and the clay-tuff contain abundant *Globigerina* shells throughout the petroleum region.

The strike of the rocks is northwest or west-northwest with dips in either direction from these lines. Local anticlines trending west-northwest have been defined on two separate lines of folding, but the general structure has not yet been determined. Evidently the beds are faulted; a fault is indicated in the southern part of the field where the shale series is exposed in juxtaposition with one of the upper limestones, which has become impregnated with petroleum residue, presumably, from contact with the shale. The prominent escarpment along the northwestern border of the field may mark another fault line. Andesites which are believed to be intrusive are encountered at numerous places in the area over which the shale series is exposed. Commonly, these outcrops are small, ranging in surface dimensions up to, perhaps, thirty feet, but there are two exposures of greater size. One of these forms a conspicuous conical hill, over 700 feet high, in the midst of the field, while the other is a sharp dome, 124 feet in height, rising out of a small plain on the coast a mile to the north-northwest of the larger hill.

Two petroleum seepages are found in the shale series in the southern part of the field and about two miles from the coast; they are about 2,500 feet apart on opposite limbs, near the crest, of an anticline which trends west-northwest. The seepage on the northern limb of this fold is on the contact of thin-bedded shale with intrusive (?) andesite—or, possibly, syenite, since this rock is more nearly holocrystalline in appearance than the normal andesite. The igneous rock, which appears to be inserted along a bedding plane in the shale, is exposed in the bed of a creek over a width of about 50 feet and a length of 200 feet. The petroleum trickles down, drop by drop, immediately on the con-

tact and in the bedding planes of the shale within a few inches of the contact. The shale shows no evidence of metamorphism along the contact. The petroleum seepage on the opposite limb of the anticline is, also, in thin-bedded shale; two shallow pits in the shale yield about one gallon of oil per day, together with a little inflammable gas. A third seepage of petroleum is encountered in a sandy phase of the clay-tuff near the coast and in the neighborhood of the larger hill of andesite. The oil oozes from fractures in the rock which appears to dip westward at a low angle. This seepage was known to the Spaniards and an abortive attempt at exploration was made at this site more than twenty years ago.

Several different forms of petroleum residue are found in Leyte. Because of the involved state of the terminology applied to this class of hydrocarbons, I shall not attempt a mineralogical classification, further than a description of the substances and their occurrence, together with the chemical analyses quoted in Table II.

In the clay-tuff at the base of the escarpment previously mentioned, with the large andesite hill between them and the petroleum seep in clay-tuff, are a half dozen small deposits of a brownish-black, schistose residue which is solid at ordinary temperatures, but liquefies with a slight rise in temperature. The solid, which is soft enough to be scratched readily with the finger nail, is brittle and the liquid flows readily with but little adhesiveness. This substance occurs in tabular lenses which generally follow imperfectly defined bedding planes in the clay-tuff but occasionally penetrate the beds along fractures. The deposits are from two to four feet in thickness and several of them have yielded, perhaps, fifty tons of material each; they do not appear to constitute large deposits, although the exploration performed so far is insufficient to justify a final statement on this point. This same class of petroleum residue is found farther south, adjacent to the coast, where it is mixed with fragments of normal clay-tuff to form a sort of bitumen-cemented breccia. These breccias are encountered just beneath the surface at different

places over an area of several acres and are known to extend downward from six to thirty feet.

In the clay-tuff at the base of the escarpment in the northwestern part of the field there occurs, also, a black solid petroleum residue with brilliant luster and conchoidal fracture. It is slightly harder than the brown residue found in the same neighborhood and does not liquefy upon being heated; it softens, however, and with intense heating forms a delicate coke. This material has been mistaken for coal by some of the prospectors in the district. It occurs in fissures with regular walls; at one outcrop the fissure is ten inches wide at the surface and widens downward to thirty inches at the bottom of the exploration pit, ten feet below the surface. A roughly columnar cleavage or structure extends across the vein, the strike of which crosses the strike of the enclosing clay-tuff nearly at right angles. The walls of the vein are sharply defined but occasional fractures extending into them are filled with the residue for several feet.

A third form of petroleum residue is viscous or slightly elastic—a black semi-solid. This material is found in different parts of the field, associated with both classes of solid residues. Its occurrence is interesting; protruding from the clay-tuff beds are small breccia domes of compact, gray calcareous rock, with the viscous petroleum residue forming an abundant cement in which the rock fragments are embedded. Fractures and even closed vesicles in the fragments are filled with viscous black oil, also. The character of the fragments in the breccia is such as to suggest that they are simply pieces of clay-tuff or, possibly, massive shale impregnated with calcium carbonate. The suggestion that the fragments in the breccias have been derived from the surrounding clay-tuff is made more plausible by the presence near the breccia domes of tubular concretions of the same material, extending across the bedding planes in the clay-tuff so as to protrude in a vertical position from horizontal strata. The central opening in these tubes and fractures and closed vesicles in the walls are, likewise, filled with viscous petroleum residue. The size and appearance of these breccia domes and tubular con-

cretions may be judged from the accompanying photographs. Chemical analyses[7] show the material of the concretions to be

Constituents.	Clay-tuff, Per. Cent.	Concretion, Per Cent.
Silica	39.78	5.73
Alumina	8.93	5.98
Ferric oxide	6.24	0.38
Ferrous oxide	3.77	1.96
Calcium oxide	17.56	28.80
Magnesium oxide	3.80	13.80
Loss on ignition	21.56	43.52
Total	99.84	99.87

impure dolomite rather than limestone and, as compared with the adjacent clay-tuff, to contain much less silica, less alumina, much less ferric oxide, less ferrous oxide, considerably more calcium carbonate and much more magnesium carbonate. If the concretions have been derived from the surrounding clay-tuff, therefore, the process has involved the removal as well as the addition of constituents, and a consequent reduction in volume, which would account for the void space in the concretions, is possible. It may be suggested further that the breccias represent large concretions which have been crushed subsequent to their formation.

The largest single deposit of petroleum residue in Leyte is an outcrop of bituminous limestone and sandstone at the head of a stream south of the town of Villaba, and in the southern part of the known field. At this place porous, coralliferous limestone and underlying loose, calcareous sandstone have been impregnated with a viscous black oil or tar. The outcrop is about thirty feet high and 200 feet long, while exposures in the bed of the stream along the face show that the impregnation persists for a distance of at least thirty feet at right angles to the face. The impregnated rocks are correlated with the tuff-sandstones and limestones in the upper part of the stratigraphic column and it is probable that the position of the outcrop marks a fault line, although positive evidence of faulting is not to be observed.

[7] Analyses of dried samples from one of the concretions and from the surrounding clay-tuff, performed by T. Dar Juan, chemist, Bureau of Science, follow.

The shale series is exposed in the opposite bank of the stream at a short distance from the deposit and at distances of one half mile in either direction along the line of the probable fault there are small outcrops of intrusive(?) andesite.

No exploration has been attempted in Leyte more than the excavation of shallow pits and short tunnels. An analysis of the Leyte petroleum appears in Table I. and analyses of the petroleum residues are contained in Table II.

TABLE I.

RESULTS OF FRACTIONAL DISTILLATION OF PHILIPPINE PETROLEUMS.

Petroleum.	Specific Gravity at 15 °C.	Percentage.[8]
Tayabas crude 3-inch well, Bahay River.[9]		
Crude	0.8325	
Gasoline, to 150° C.	0.770	39.0
Kerosene, 150° to 300° C.	0.850	44.5
Heavy oils, 300° to 400° C.		15.5
Residue, above 400° C.		not determined
Sulphur		absent
Paraffin scale		8.1
Cebu crude,[10] well at Toledo	0.885	
Gasoline, to 150° C.	0.762	6.20
Kerosene, 150° to 300° C.	0.832	42.32
Heavy oils, 300° to 375° C.	0.901	38.30
Residue above 375° C.		13.17
Leyte crude,[11] pit at Villaba	0.8597	
Gasoline, to 150° C.		5.4
Kerosene, 150° to 300° C.		33.7
Heavy oils, 300° to 400° C.		55.3
Residue, above 400° C.		5.6
Paraffin scale		8.14

the weights are expressed.

CHARACTER OF PHILIPPINE PETROLEUM.

Philippine petroleum is characterized by a paraffine base and in the case of the Tayabas petroleum, by a remarkably high proportion of light oils. The product from Tayabas is lighter than that from either Cebu or Leyte but otherwise the petroleums

[8] Percentages by volume except in the case of the Leyte petroleum where the weights are expressed.

[9] Richmond, G. F., *Phil. Jour. Sci.*, Sec. *A* (1910), *5*, 1.

[10] Mr. H. C. Brill, analyst, Bureau of Science, Manila.

[11] Mr. A. H. Wells, analyst, Bureau of Science, Manila.

from each of the three fields are similar. The Tayabas petroleum is wine-red in color and has a gravity of 38° to 39° Baumé while the Cebu and Leyte petroleums are brown and have gravities of 28° and 33° Baumé, respectively. In the following table are the results of fractional distillations of petroleum from each of the three fields. The high quality of the Tayabas petroleum has been confirmed by several analyses of different samples.

In Table II. are recorded chemical data on several of the petroleum residues from Leyte.

TABLE II.[12]

CHARACTERISTICS OF NATURAL PETROLEUM RESIDUES FROM LEYTE, PHILIPPINES.

Material.	Specific Gravity.	Total Soluble in Carbon Disulphide.	Fixed Carbon.	Softening Point.	Paraffin Scale.
Lustrous, black solid.....	1.068	94.53	26.62	coke	3.89
Brown, schistose solid.....	1.026	93.79	7.68	55° C.	11.05
Viscuous semi-solid.....	1.016	81.84	6.59	35° C.	0.30
Bituminous sandstone.....		61.85			0.13
Bituminous limestone.....		8.84			
Brown, schistose solid mixed with clay-tuff.....		25.12			5.42

THE COMMERCIAL POSSIBILITIES OF PHILIPPINE PETROLEUM.

The surface indications of petroleum in the Philippines do not justify any unqualified prediction that petroleum will be developed there in commercial quantity; neither can it be stated certainly, on the other hand, that there is no chance of a commercial exploitation. The possible fields merit further examination and probably parts of them will be found to merit intelligent exploration by drilling. The various seepages demonstrate the presence of at least small quantities of petroleum. The petroleum residues in Leyte prove the former presence in the rocks of that region of an aggregate quantity of petroleum of commercial proportions. Whether or not a similarly large quantity remains in that field and whether the petroleum there and elsewhere is present under conditions which will permit of its discovery through drill holes, is undetermined. The structure at places in each of the prospective fields is favorable for the accumulation

[12] Mr. A. S. Arguelles, analyst, Bureau of Science, Manila.

and retention of any petroleum that may be present beneath the surface. Some of the anticlines are sharp, or closely folded, and broken but the close grain and softness of the predominant beds might be expected to effect a sealing or closing of the openings formed as a result of this condition, and so to prevent the escape of petroleum along such openings; moreover, there is a subordinate number of less closely folded anticlines. The accumulation of petroleum in the Leyte region appears to be related to the intrusion of igneous rocks into the containing beds, a condition which renders the success of drilling uncertain and the proper location of test wells difficult.

Perhaps the least favorable aspect of the geology of petroleum in the Philippines is the lack of well-defined porous beds adequate to serve as a reservoir for accumulated petroleum. The thin-bedded sandstones in the bedded-shale series do not promise much in this respect and the sandstone observed at places in Tayabas, overlying the petroliferous shale, seems not to be continuous and contains no trace of petroleum where it is exposed. It may be argued that a light, fluid petroleum, like that in Tayabas, would leave little trace of its passage through an open sandstone, but the fact remains that the petroleum does not appear at the surface in rocks that could be expected to yield large flows from drill holes. Again, the observed petroliferous portion of the shale is not extensive in its thickness, although, to be sure, it is uncertain just how far below the top of the shale series the petroleum horizon may extend. Finally, the remains of organisms whose decomposition might have formed petroleum are not to be observed in numbers sufficient to have yielded large volumes of petroleum. If no petroleum is present other than that which may have arisen from the decomposition of *Globigerina,* assuming that *Globigerina* are a source of petroleum, then but little petroleum is to be expected, since the *Globigerina* form a relatively small proportion of the rock in only a part of the stratigraphic column.

On the other hand, a paraffin-base petroleum is recovered commercially in countries adjacent to the Philippines, from beds of the same age and same general character as the petroleum-bear-

ing rocks in the Philippines. Japan produces nearly 2,000,000 barrels of petroleum annually from Tertiary sandstone and tuff beds, alternating with shale.[3] Formosa (Taiwan), immediately north of the Philippines and similar geologically to the Philippines, produces 15,000 barrels of petroleum annually from Miocene shales and sandstones. Southern Borneo, Sumatra, and Java, southwest of the Philippines, are important sources of petroleum. In Sumatra a large production of petroleum, similar in quality to that from Tayabas, is obtained from Miocene and Pliocene sandstones interbedded with shales and clays.[14] One of the principal Sumatran fields has been developed on acute anticlines similar in structure to those observed in Tayabas. The evidence from adjacent countries, therefore, points toward the probable success of exploration in Philippine petroleum fields, while preliminary studies in the Philippines do not, to state the case least favorably, reveal prohibitive conditions. Under the circumstances the possible fields in the Philippines certainly deserve further attention.

The natural petroleum residues in Leyte have not been utilized. There is a demand in the Philippines for asphalt roads and pavements but the pure residues contain so much paraffin as to render them brittle and so unfit for paving purposes. Even if these deposits prove to be large, therefore, the raw product will find no Philippine market and high freight rates militate against exportation on a profitable basis. It has been suggested that these residues might be distilled so as to yield gasoline, kerosene, lubricating oils, etc., for which there is a market in the Philippines. The bituminous limestone, or rock asphalt, which appears to be present in quantity, proves upon analysis to contain but little paraffin, a deficiency due, possibly, to the removal of part of the original paraffin content as the petroleum filtered through the pores of the rock. The petroleum residue in the bituminous limestone is distinctly viscous and adhesive and the general character of the material is such that it probably can be used for paving.

[13] Iki, T., Mem. Geol. Surv. of Japan (1910), No. 2, 29.

[14] Tobler, Dr. August, *Tidschrift van het Kominklijk Nederlansch Aardrijkskundig Genootschap.* (1906), Tweede Serie, *23*, No. 2, 199.

OCCURRENCE, GEOLOGY AND ECONOMIC VALUE OF THE PITCHBLENDE DEPOSITS OF GILPIN COUNTY, COLORADO.

PERCY R. ALSDORF.

The large amount of public interest that has recently been manifested in radium, because of its apparent curative effects on cancer, its healing influence in other diseases, and its apparent stimulation of the growth of the vegetable kingdom, makes it a very interesting study. Inasmuch as all radium is derived from some ore of uranium, and all ores of uranium have had their origin, it is generally accepted, in pitchblende, and the fact that one of the important commercial sources of pitchblende for the entire world occurs in Gilpin County, Colo., this paper is especially devoted to the study of that region.

Radium.—Radium is the product of the disintegration of uranium and is in equilibrium with it in the ratio of 1 to 3,400,000.[1] It belongs to the alkaline-earth group of minerals, of which barium is a member.

It is continually disintegrating, giving off minute particles of itself, known as emanations, and producing alpha, beta, and gamma rays. These emanations are yielded very slowly. The estimate has been made that two thousand years will be required to give off one half and twenty thousand years to lose practically all of its energy.

These rays have numerous new physical characteristics, one of them being the effect of ionizing air immediately in contact with them. Electric currents are readily discharged through ionized air in proportion to the ionization, and the electroscope has been devised to take advantage of this feature, by discharging a measured electric charge by a measured quantity of radio-active mate-

[1] E. Rutherford, McGill University, and B. B. Boltwood, of Yale University, *American Journal of Science,* Series 4, Vol. 22, 1906.

rial; thus knowing the rate of discharge, calculation of the activity can be readily made.

Inasmuch as pitchblende is in equilibrium, that is, it has a constant quantity of radium and radium emanations, the calculation of the percentage of uranium oxide contained in an ore may be made with surprising accuracy, by means of the measurement of the activity.

In 2,000 pounds of pure pitchblende, it is estimated that there are 260 milligrams of elemental radium; in one pound of pitchblende there are .13 milligrams of radium, or 130 micrograms (a microgram being one millionth of a gram).

Geology.—In "Pitchblende Deposits of Gilpin County,"[2] Mr. E. S. Bastin states:

"The predominant rocks of Quartz Hill and neighboring parts of Gilpin County are pre-Cambrian igneous and sedimentary rocks and Tertiary intrusive rocks in the form of dikes and stocks.

"The oldest pre-Cambrian rocks are those of the Idaho Springs formation, predominantly a quartz-mica schist, which is believed to be a metamorphosed sediment. This schist is intruded by pre-Cambrian granites of at least two ages—an older granite that has been dynamometamorphosed and is commonly massive. Granite pegmatite offshoots from both these granites are numerous and in places intrude the Idaho Springs formation so intimately as to produce an injection gneiss. Where the Idaho Springs formation lies near or is inclosed by considerable bodies of granite rock, it has commonly been contact-metamorphosed to a hornblende schist.

"All the pre-Cambrian rocks are intruded by dikes and stocks of monzonite porphyry and of bostonite porphyry (entirely orthoclase). These are believed to be of Tertiary age.

"The mineral veins of the vicinity are the result of combined fissure filling and replacement along a series of fractures characterized by easterly to northeasterly strikes and commonly by steep dips. The veins cut both the pre-Cambrian rocks and the Tertiary intrusives. On the basis of mineral composition they can be divided into two types, which may be designated the pyritic

[2] Professional Paper No. 90, U. S. Geological Survey.

type and the lead-zinc type. They have been worked principally for their precious metal content, though yielding also considerable amounts of copper and lead.

"The principal primary minerals of the pyritic type are pyrite and quartz; chalcopyrite and tetrahedrite are almost invariably present in subordinate amounts, and enargite, fluorite and rhodochrosite occur here and there. The primary minerals commonly present in the veins of the lead-zinc types are galena, sphalerite, pyrite, chalcopyrite, quartz and calcite. Some parts of the district are characterized solely by one or the other of these types of mineralization, but in many of the veins both types are present. In such veins it has been demonstrated by repeated exposures that the lead-zinc type is somewhat later than the pyritic type and that the minerals of the former commonly line vugs or fractures in those of the latter. It is believed, however, that the lead-zinc mineralization followed close upon the heels of the pyritic mineralization, and that the two types represent merely successive epochs in one great vein forming; that both came from a common deep-seated source, the ore-bearing solutions following the monzonite intrusion after a short interval.

"Sulphide enrichment in the upper portions of many veins of the lead-zinc type has developed secondary silver minerals in considerable abundance, and such veins are known as 'silver veins,' their principal value being in that metal."

In the general description of Gilpin County geology, as quoted above from Mr. Bastin, the particular pitchblende district has these characteristics and may be particularized as follows:

In the town of Russel Gulch, south of the Gomer shaft building, a line running irregularly due north through to Kings Flats, north of the town of Bald Mountain, defines the Idaho Springs schist to the west and the older pre-Cambrian granite above mentioned to the east. From this point, south of the Gomer shaft, a line running 10 degrees north of east about 2,700 feet, divides roughly the Idaho Springs schist on the south from the older granites to the north. From this point north, a line bearing 10 degrees east to Nevada Gulch divides roughly the Idaho Springs formation to the east from the older granites to the west.

In this rough rectangle are also intrusives of younger granites, batholiths and dikes.

Porphyries.—The bostonite dikes, each two or more miles long, cut through this district on the northern and southern portions with strikes approximately east and west, the north one being commonly known as the California Dike, because the California vein has been formed closely to it. There are many other productive mines adjacent to it.

The south one cuts across near the Wyandotte shaft and forms the south wall of the Topeka vein for a long distance.

From a point immediately west of the Wyandotte shaft a dike starts north and gradually turns to 30 degrees west, on through to Kings Flats, but a split makes off at the crossing of the Ethan Allen vein, as a branch which bears north 50 degrees west.

From a point about 40 feet west of the Wyandotte shaft a second dike starts north 40 degrees west, and bends to north 80 degrees west, at the west end of the Kirk mining claim.

At the 350 level of the Wyandotte, by means of drifts and crosscuts, all three of the last mentioned porphyry dikes are seen and the differences in texture may be noted. It would appear that the last two dikes mentioned, viz., the ones bearing northerly, are the older, since the east and west one cuts across them.

The last two dikes have comparatively high radio-activity from the Wyandotte to the German vein. At a point on the Mayflower claim of the Calhoun group a specimen from the second or westerly dike also gave high radio-activity and a qualitative reaction for uranium. This dike is also radio-active from its beginning to its crossing of the Ethan Allen claim.

It is curious to note that all of the pitchblende producing mines, or those in which pitchblende has been reported, are located in the immediate vicinity of these radio-active porphyry dikes, and in a rectangular area not to exceed 2,000 feet east and west by 2,250 feet north and south.

Veins of the Section.—As noted above, Mr. Bastin gives two distinct types of mineralization of Gilpin County in the same general period of time.

My observations in the pitchblende deposits lead me to believe that prior to the precious metal deposition and mineralization, as mentioned by him, there occurred a fracturing of the country about the time of the intrusion of the two radio-active porphyry dikes, and that immediately subsequent to their intrusion the filling and replacement occurred in this area of the existent fractures by deep-seated solutions, bearing uranium, some pyrite and galena. These several minerals were deposited in the fractures, and replaced the alkaline earths of the granites, so as to produce a type of vein in which, in the granites, there are no well-defined "walls," but disseminated mineralization.

The pitchblende veins are cut across, followed and obliterated by the subsequent faulting and vein filling of the period of the precious metal veins.

I have not been able to find any evidence that the pitchblende solutions deposited any gold and silver in the veins at their first filling, and express my opinion that exploration and study in the future will find little if any precious metal values connected with this period of deposition. The gold- and silver-bearing sulphides found in connection with them, so far as I have observed, have been enrichments and replacements of the later sulphide vein period, or still later secondary replacements, which sometimes take the form of free gold in the pitchblende.

Mr. Forbes Rickard, in speaking of the German-Belcher-Wood deposits, states:[3]

"Ore deposits of this district furnish two types of ore, one being characterized by pitchblende, with accessory pyrite in varying quantity, with sphalerite and galena in subordinate quantities, and sometimes marcasite and stibnite, but in a much less degree; the other type of ore includes the minerals, pyrite, chalcopyrite, sphalerite and galena, with varying gold and silver content.

"It is axiomatic in these mines that as pitchblende comes in the gold goes out, and as a matter of fact, the pitchblende ore rarely contains more than two to four dollars in gold per ton; what gold is present is largely in metallic form, which makes it susceptible

[3] U. S. Geological Report, 1913, by Frank L. Hess.

to concentration with pitchblende, making a comparatively high grade product."

Pitchblende.—Pitchblende, whose mineralogical name is uraninite, has a complex formula, being composed of uranium as UO_2 and UO_3, in varied proportions. An analysis of Gilpin County pitchblende by W. F. Hillebrand, gives:

	Per Cent.
UO_3	25.26
UO_2	58.56
ZrO_2	7.59
CeO_2	.22
PbO	.70
ZnO	.44
FeO	.32
MnO	.16
CaO	.84
H_2O	1.96
N & He	.15
SiO_2	2.79
P_2O_5	.22
As_2O_5	.43
$CuFeS_2$	.12
FeS_2	.24
	99.95

Calculating all the uranium as UO_2, we find 82.36 per cent UO_2. Specific gravity is 8.068.

Two occurrences of uraninite have been noted by geologists. One is primary in the igneous rocks, and one is due to depositions by hot solution in the metamorphic and igneous rocks. A third form in which uranium appears I have observed but have not sharply identified. It has a low specific gravity, probably from 4.5 to 6.5, is very prone to slime in milling operations, and is apparently encrusted along the faces of the rock instead of being massive. The mineral is probably a product of deposition from relatively cold acid solutions, because it is intermixed intimately with marcasite. This variety is of no economic value, as, because of its low specific gravity and sliming qualities, it is very difficult to concentrate by wet methods. It is lost in flotation, and in dry concentrations it comes over with the middlings on the

concentrating tables along with minerals of specific gravity of four to five. I have never observed its occurrence below 160 feet from the surface.

The occurrence of pitchblende in Gilpin County has not been noted in the primary deposits heretofore, but in examination of the two porphyry dikes crossing this section, I have found specimens away from any vein-influences. On account of their comparative high radio-activity, I had a microscopic examination made, which disclosed small, dark crystals, finely disseminated through the mass of the porphyry. There were no signs of alterations or replacements. The dikes also gave uranium reactions.

The commercial quantities of pitchblende are all of epigenetic nature. They are found in the older altered granites, in the younger intrusive granites, in the granitic schists and gneiss, and occasionally in the Idaho Springs schists, close to or in contact with the igneous rock. I have not observed any enriched places in the porphyries, either along their contacts or cutting through them, but the means of studying them to date have been very meager.

In the Calhoun, Wood, Wyandotte and Leavenworth workings, I have observed that the pitchblende veins are clearly older than the Calhoun and Wyandotte veins, which in turn are older than the Wood or Leavenworth sulphide veins. The pitchblende deposits occur in the oldest granite, which is massive, often contorted and intruded; in the younger granite, which is fine-grained, aplitic in character; in the metamorphosed granites, gneiss, and schists derived from these granites; but its occurrence in the Idaho Spring schists is noted only in one or two instances. It has probably been brought into the schist mechanically by faulting movements of the Calhoun vein, since the microscope enables us to detect granite particles which are foreign to the surrounding country rock.

Its absence may be due to three factors, although the ore-bearing solutions penetrated this area.

First, because the necessary precipitating element was absent in these Idaho Springs schists.

Second, because, if precipitation did occur, and pitchblende veins were formed, subsequent percolations of the mineral-bearing solutions and underground waters redissolved it and carried it away. These schists are of a porous character, and could have permitted circulation more readily than the granites and granitic schists and gneiss.

Third, opportunities for the observation of these veins are rare. They are unattractive as producers of gold and silver, and the few observed cases are not sufficient to establish a universal rule. I am inclined therefore to leave the question of the occurrence or non-occurrence of pitchblende in the Idaho Springs schists open until further developments, with this statement, that no occurrences have been reported to date.

Sulphide Veins Bearing Gold and Silver.—The sulphide veins spoken of above by Mr. Bastin are in my opinion later than the pitchblende veins. Mr. Bastin suggests that these veins followed closely the monzonite intrusions. If, as I have reason to believe, the monzonite was later than the bostonite dikes, which are radioactive, the veins following the monzonites would be due to a later mineralization than that which yielded the pitchblende.

These veins are followed by other later fissuring and filling, so that there are present three types. Their relative ages are designated in the mine workings by successive re-openings, faultings and brecciation of the older veins by the later ones.

For example, there is a branch of the Mayflower vein in the Calhoun workings, which has been opened from surface to 800 feet in depth. This vein must have been earlier than the Calhoun vein, and the Calhoun vein, being formed along a fault fracture, has followed its course a short distance. At point of first intersection a body of pitchblende appeared, assaying 0.04 oz. gold. The fault movements along the Calhoun vein polished portions of the pitchblende and gave the mineral solutions access to these faces. The solutions deposited gold, silver, lead, zinc, copper and iron, and yielded ore assaying 13 ozs. gold. At another place these later sulphides replace a portion of the pitchblende, yielding ore containing 18 per cent. U_3O_8 and 19 ozs. gold—purely

a result of replacement during the period of mineralization of the Calhoun vein.

Sulphide Veins.—At another place the original pitchblende vein was broken up by the faulting movement of the Calhoun vein, and almost entirely obliterated by the replacing actions of the mineralizing solutions. There remains here and there only an occasional fragment, which escaped by reason of its original massiveness, or because protected by impervious silica from the dissolving solutions.

In other places the same vein appears to have been porous in character and to have permitted the dissolving and mineralizing solutions to exert their influence some distance away from the Calhoun vein, so that only occasional bunches of pitchblende are found.

At other mines these so-called pitchblende spurs occur under similar conditions, as I have noted, but no one has looked upon them until now as the real pitchblende veins.

Westward along the main Calhoun vein, the Leavenworth sulphide vein crosses it and faults it some 10 feet, with a slight secondary enrichment on either side.

Eastward along the main Calhoun vein, the Woods Sulphide uranium-free vein crosses the Calhoun, faulting it about 18 inches, and also secondarily enriching it.

All of these veins contain gold, silver, chalcopyrite galena, sphalerite, and pyrite, with quartz gangue, and all replace earlier minerals of the country rock.

Geological History.—The history, then, of this interesting section may be outlined in this chronological order:

1. Archean rock, the first solid formation.
2. Sedimentary rock, pre-Cambrian period, metamorphosed by heat and pressure into the Idaho Springs schists.
3. Intrusive granites, dikes and batholiths of the older types, originally massive in character, but in some cases metamorphosed into schists and gneiss.
4. Younger granites, dikes and batholiths of an intrusive nature

cut through all older formations and are of a finer grained texture (aplitic).

5. Intrusions, probably Tertiary or post-Tertiary, of bostonite dikes, which came from a uranium-bearing source. Very little faulting is involved by their entrance.

6. Mineralization of the fissures by deep-seated hot solutions, which are either genetically connected with the bostonite dikes or with their source. They deposited some galena, zincblende and pyrite, but little precious metals.

7. Intrusions of other bostonite and monzonite dikes, with extensive faulting.

8. Mineralization of these fissures and vein filling from deep-seated sources by hot solutions, depositing minerals containing gold, silver, lead, zinc, copper and iron, which replaced older minerals in veins and country rock. Examples, Calhoun and Alps veins.

9. Other new faultings and reopenings along existing fissures.

10. Mineralization by hot solutions, as above, making later deposits in the older veins.

11. Replacements by cold water and acid solutions, which dissolved some pitchblende and replaced it with marcasite, or which left vugs frequently having no uranium, leading us, by electroscopic examinations, to suspect the presence of radium as an insoluble sulphate.

THE OCCURRENCE OF THE OLDER BEDS IN STRUCTURAL DEPRESSIONS.

By Dorsey Hager.

It is presented as almost an axiom in geological courses that where older beds are surrounded by beds of younger age, a doming exists. This has been so generally accepted that it is a shock to those field men who find that in some cases the exposure of older beds indicates a structural depression rather than a doming.

The writer came to Oklahoma from California where the folding in the oil fields is intense. In the Pacific coast oil-fields, exposures of older beds surrounded by younger beds means a domed condition, unless faulting has occurred. It was a rude awakening to find that in Oklahoma and Kansas, "structural highs" or domes, in a number of cases, carry the younger beds on top of the structure, and that older beds are exposed in the depressions or "lows" along the axis of the fold.

Fig. 19 illustrates this condition clearly. A good example occurs on an anticlinal fold running from Oklahoma into Kansas. This fold is known as the Dexter anticline. It may suffice to state that good examples of similar conditions are shown on terrace structures. A fold two miles west of Ralston and one three miles west of Skedee, Oklahoma, afford excellent types. Both these folds show older beds in their "structural lows," or depressions, and the younger beds on the crests, or "highs," of the fold.

In Fig. 19 the dotted lines indicate structural contours based on a heavy cherty limestone, of which the contact is indicated by the heavy black lines.

The red lines indicate a contact between a second heavy limestone and a heavy shale which underlies the second limestone.

The cross-sections *A–A*, *B–B*, and *C–C* indicate conditions

found on the fold. The cross-section *D–D* along the axis illustrates doming along the strike of the fold.

A–A shows the second limestone capping the apex of a dome.

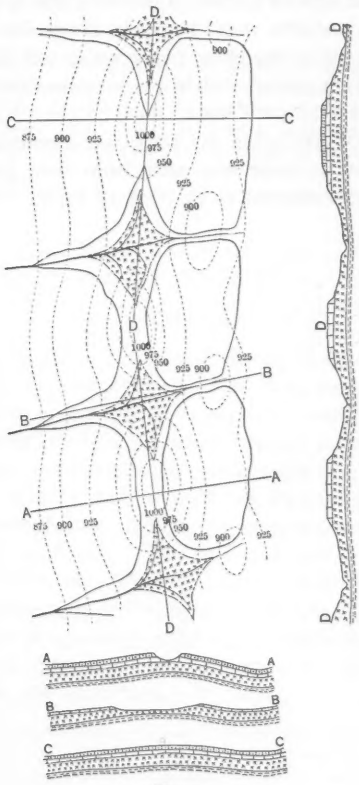

FIG. 19.

B–B shows the older beds in the depression along the axis of the anticline.

C–C shows the topmost limestone capping the structure.

If one is careful in reading the dips of the beds there will be

little danger of going wrong; but if one adheres to the theory that the occurrence of older beds indicates a doming, then one may occasionally find his supposed domes to be depressions.

This peculiar type of erosion is probably due to the following cause: As the meteoric water naturally drains into the syncline from the high points, the effect of the water will be greater, due to greater solvent action, and to the erosive action of a larger volume of water in the "lows" than on the "highs."

To Oklahoma geologists the foregoing discussion may seem unnecessary; but to those who come from other places it is important to be forewarned as to what to expect.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

THE BAKU OIL FIELDS: DISCUSSION OF PAPER BY A. ADIASSEVICH.[1]

L. G. HUNTLEY.

To those who are familiar with the oil fields of North and South America, the recent review of the Baku fields of Russia by Mr. Adiassevich presents some remarkable contrasts. I believe these Baku fields still hold the world's record for the amount of oil produced per acre drilled: with the possible exception of Mexico. And in Mexico, exclusive of the Panuco field, no pools have as yet beeen defined, and the measurement of a definite producing area is impossible. The fractured and channelled limestone in which Mexican oil is found also tends to make impossible such a measurement of producing zones on a basis of saturation.

The production figures given by Mr. Adiassevich for the fields of the Baku district, with production per acre calculated by the present author, are as follows:

	Since	Area.	Total Production.	Barrels per Acre.
Balakhany	1870	857.5	279,100,000	325,492
Sabunchy	1878	877.5	594,100,000	677,037
Ramany	1890	243.0	240,500,000	989,630
Bibi-Eibat	1880	520.0	268,500,000	516,346
		2498.0	1,382,200,000	Average 553,322

[1] *Trans. A. I. M. E.*, Vol. XLVIII.

By calculation from Washburne's figures[2] of 524 barrels of oil extractable from an acre foot of saturated sand; and assuming that these Russian fields produced oil only from below the acreage actually developed by the drill; the foregoing figures indicate thicknesses of saturated sand from 500 to 1,900 feet, and averaging 1,056 feet for all four fields. These thicknesses are manifestly impossible, and drainage has actually taken place from much greater areas than those drilled.

While Mr. Adiassevich states that the producing series of oil sands is 600 feet in thickness, yet the log of a typical well given by Beeby Thompson[3] shows that in this series or formation there are less than 130 feet of "oil sand," occurring in pays varying in thickness from 4 to 27 feet. However, only from the lowest sand of 27 feet is oil produced in the well described. The small area developed in each of these fields, combined with the impervious character of the clay beds interstratified with the sand, and the occurrence of water sands intervening between oil sands, preclude the possibility of the upper oil sands in the series being drained to any important extent through the lowest or producing stratum. However, Redwood and others mention having noticed a connection between the flow of certain wells producing from different horizons. Such oil beds are presumably not far apart stratigraphically. and the connection may be accounted for in a number of ways, viz., (*a*) fracturing incidental to the geological folding; (*b*) playing out of an intervening clay bed, having as a corollary the joining of two sand bodies, allowing the draining of the upper by a well producing from the lower split; or (*c*) a combination of (*a*) and (*b*). That is, a small lens or disk of sand may have been distorted by geological folding, and have kept open a connecting channel between two sand bodies. Or (*d*) there may have been mistakes in correlating the different beds, due to the playing out of certain very local lenses and the coming in of others, so that in reality both wells were producing from the same sand body.

Of course, the chances for such a connection decrease very rapidly a short distance above the producing stratum with the

[2] "The Estimation of Oil Reserves," *A. I. M. E.*, February, 1915, p. 469.
[3] "Petroleum Mining," p. 71.

increasing number of clay and marl beds passed, in unconsolidated sediments which tend to bind and close any joint cracks or fractures which might once have been formed. Any vertical connection between oil beds would evidently be limited to those few not far above the producing sand. All wells do not produce from the same horizon, and the present producing sands have been penetrated only after the exhaustion of shallower "pays."

Beeby Thompson says the average thickness of the producing sand in the Baku fields is about 20 feet. However, he uses a thickness of 40 feet in his calculation of the areas drained by various wells, which is probably a very fair average even under the conditions named above. However, as there has been a great deal of thrusting and differential movement between beds in this region, it is probable that drainage channels, or more correctly, lines of less resistance to flow, have been set up. Drainage would therefore tend to be greatest along such directions, as well as being influenced by the shape of the sand body. This may be stated in another way by saying that the lines of greatest accumulation will be in certain directions determined by the above factors.

In the California fields in the United States, Bell estimates an average thickness of oil sands as 50 feet, with a possible extraction of 800 barrels per acre foot of producing sand. This is somewhat higher than the result obtained by calculation from Washburne's formula; the difference being accounted for by the fact that California sands in some instances have a higher saturation than 15 per cent. which he assumes, and the percentage extraction is higher in California than in many other fields. Geological conditions in some California oil fields more nearly resemble those of the Baku fields of Russia than they do those of any other part of the world. The great quantities of sand thrown out by wells, accompanied by a steadily increasing production for some months after being drilled, are related phenomena common to both fields.

In the cases where production increases for some months after drilling in a well, accompanied by the expulsion of large quantities of sand, the author believes the increase due to the extension of the cavity in the sand around the well. The free drainage area or surface is thus gradually increased, and in many cases extends

in long arms or channels along the top of the sand body, *i. e.*, along the contact with the overlying stratum. The falling in of the roof of such a cavity around the well frequently bends or distorts the lower part of the well-casing, and sometimes ruins the well. In Mexico, where the oil is produced from channelled and cavernous limestone zones occurring along old fracture lines, whose walls are not inclined to cave or collapse, and which communicate for long distances, the author ventures the prediction that certain wells in that field will far exceed in total production any well which as yet has been drilled in other fields.

In soft unconsolidated sands such as those producing oil in California and Baku, the formation of permanent drainage channels through the sand body itself, rather than on the top, is an impossibility. However, there may be continuous beds of gravel or more porous sand interstratified in the main body, along which seepage will proceed more rapidly and extend to greater distances from the well. But drainage channels primarily caused by the flow of oil and gas could not be maintained for any but very short distances. However, below a differentially hardened "shell" within the sand body, drainage channels might be maintained.

Calculation on the basis of Washburne's method of estimation gives the following results showing the radius of territory drained in each of three pools in the Baku district:

Thickness of sand assumed at 40 feet:

Quantity of sand per acre-foot (bbls.)	7,758
Saturation factor	.75
Extraction factor	.60
Porosity (assumed)	.25

Balakhany pool (857.5 acres). Production 279,100,000 bbls.

$40 \times 7{,}758 \times .25 \times .75 \times .60$ — 35,000 bbls. / acre.
— 8,000 acres drained.
— 10,530 ft. radius.
— 2 mile radius.

Sabunchy pool (877.5 acres). Production 594,100,000 bbls.
— 17,000 acres drained.
— 15,350 ft. radius.
— 3 mile radius.

Romany pool (243 acres). Production 240,500,000 bbls.
—6,870 acres drained.
—9,760 ft. radius.

When one considers that the Sabunchy pool, representing a drilled area of 877.5 acres, or a radius of about ½ mile, has drained an area with a radius of approximately 3 miles, the figures are startling. It would still be remarkable if the aggregate thickness of producing sands assumed to be as high as 80 feet. It is very probable that salt water has been behind the oil body, and aided the movement of oil up the sides of the anticline, so that it must not be assumed that an area of this radius now exists on all sides of the producing wells which has been drained of all oil. The extent of this final encroachment can not be known definitely. That is, at what period in the pool's history equilibrium will be reached, and the water body cease to move up the sides of the anticline. However, valuable evidence can be obtained by carefully watching the production curves of a large number of wells, in connection with the declining pressure of the pool, together with any evidence of encroaching saltwater in the pay sand.

The statement made by Mr. Adiassevich (p. 619–20) that upon the evidence of seepages at the outcrop of lower beds in another locality, there would be found three series of oil-bearing sands in the Balakhany-Sabunchy-Ramany field, of which only the upper had been worked, should have been made with qualification. Certainly no one has a right to assume that because a series of sands is oil-bearing at the outcrop that they will necessarily contain oil in large quantities at another point. Even though structural conditions are favorable, there are too many unknown factors to warrant such an unqualified statement. It is to be hoped that the two lower (and as yet untested) series of oil sands will prove as prolific as that already developed, but it is premature to confidently predict such a phenomenal result.

L. G. HUNTLEY.

ORES, MAGMATIC EMANATIONS AND MODES OF IGNEOUS INTRUSION.[1]

DISCUSSION OF PAPER BY B. S. BUTLER.

Professor Daly's discussion of Mr. Butler's paper[2] is of special interest to me, who was associated with Professor Daly at Boston from 1907 to 1912, and spent most of the field seasons of 1911, 1912, and 1913 studying the ore deposits of Utah in cooperation with Mr. Butler. Of the several mining districts and I visited, those of the Cottonwood-American Fork region and the Tintic district offered the best opportunities to study methods of igneous intrusion.

Cottonwood-American Fork Region.[3]—Conditions in the Cottonwood-American Fork region are well expressed by Mr. Butler's statement (page 116) that "the space occupied by the igneous material constituting the stocks was formed in large part by the pushing aside and doming of the earlier rocks." Professor Daly notes that Mr. Butler's "elaborate section" expressing the latter's idea of the underground relations for three hypothetical stocks "clearly shows that the country rocks were *not* pushed aside" and therefore "squarely contradicts the text." It is evident to me, from my personal acquaintance with the region, that Mr. Butler's section was drawn solely to show the relations of ore bodies to slightly and deeply eroded masses of igneous rock, and did not pretend to indicate the complicated structural details near the igneous contacts. Mr. Butler, with the genesis of the ore deposits uppermost in mind, evidently neglected the accurate representation of intrusion processes; Professor Daly, with the genesis of igneous rocks engrossing his attention, naturally looked especially for data on methods of intrusion.

Adequate representation of the complex structures around the igneous stocks in either the Cottonwood-American Fork region

[1] Published by permission of the Director of the U. S. Geol. Survey.

[2] Vol. X., No. 2, pp. 101–122.

[3] A short report on this region by Mr. Butler and G. F. Loughlin has just been published as a part of Bull. U. S. Geol. Survey, No. 620 (contributions to ECONOMIC GEOLOGY, 1915, Part I.).

or the Tintic district is impossible in a single section; only an elaborate stereogram or model could serve the purpose properly. In the Cottonwood-American Fork region pre-Cambrian and Paleozoic sediments are irregularly domed around a stock of granodiorite. The dips of the pre-Cambrian slates and quartzites in Big Cottonwood Canyon, on the north side of the stock are northward, away from the stock, and in places the beds are very steep and even contorted. Along the eastern border of the stock the dips of upper pre-Cambrian and lower and middle Cambrian strata are also away from it, and the formations are broken by steep reverse faults along which the blocks adjacent to the stock moved upward about normal to the igneous contact. Along the southern boundary of the stock only Paleozoic limestones, metamorphosed and dipping away from it, are exposed. Comparison of the southern with the eastern and southeastern boundaries suggests strongly that the great series of quartzites that formerly occupied the position of the present stock were up-faulted above the level of the present surface by the upward thrust of the intrusion and have since been eroded. To one observing only the western and southern boundaries, however, the idea of up-faulting and erosion of quartzite would not occur so readily, but the doming of the limestone would still be an important feature.

The impression gained from the evidence expressed at the present surface is that the granodiorite magma made room for itself by pushing upward or doming a great thickness of pre-Cambrian and Paleozoic rocks; and that along the eastern and southern boundaries the shearing strength of these rocks was overcome and doming gave way to faulting. The method of intrusion at greater depths, where the resistance of the overlying rocks was too great to permit doming, is open to speculation. The magma must have made room for itself in some way, and as its thrusting power was inadequate, some process of stoping appears most plausible.

Study of the upper contact of the stock proves that many small apophyses of the granodiorite cut across the bedding of the quartzitic rocks and send branches along the bedding. In other words they represent the arrested process of the stoping of rock that had already been domed. Inclusions of these roof rocks in the grano-

diorite however are very scarce, although the granodiorite along Little Cottonwood Canyon is exposed to a maximum depth of 5,000 feet. Inclusions of dark dioritic rock are abundant, but their composition is such that they can not be regarded as recrystallized roof rock. The granite itself is very uniform in mineral and chemical composition. This evidence tends to indicate that after the up-thrusting force of the magma had subsided some stoping took place; but that very little rock was displaced by this process and that very few of the stoped blocks sank for appreciable distances in the viscous magma.

Tintic District.—Evidence around the principal monzonite stock in the Tintic mining district, though somewhat different from that just discussed, leads to the same general conclusion. Here the sequence of sedimentary rocks is generally the same as in the Wasatch Mountains. The monzonite was intruded near the axis of a great syncline whose western limb is about vertical. It did not cause any doming, but a number of faults have been found that were produced wholly or in part by the intrusion. These faults are considered in detail in a report which has just been completed.[4] The diverging character of the vertical strata north of the monzonite contact suggests that the monzonite may have made room for itself to some extent by prying them apart. Evidence of stoping is much more prominent than in the Cottonwood-American Fork region, but stoping as a means of making room for the monzonite stock appears to be secondary in importance to faulting. The following is a very summary account of the intrusion faulting.

One fault of relatively small displacement extending northward through the Apex and Centennial Eureka mines is of special interest in showing the time of its formation. It faults a dike of rhyolite porphyry whose intrusion was a little earlier than that of the monzonite but is older than the ore bodies whose deposition followed closely after the monzonite intrusion. The only fissures formed between the time of monzonite consolidation and ore depo-

[4] Lindgren, Waldemar, and Loughlin, G. F., "Geology and Ore Deposits of the Tintic Mining District, Utah." To be published as a Professional Paper of the U. S. Geol. Survey.

sition are characterized by little or no displacement, but the fault in question is a compression fault with a displacement of 300 feet or more, the east wall moving northward and upward away from the monzonite. Another fault similar in general character and magnitude of displacement extends east of north through the Emerald and Grand Central mines. Neither of these faults offset the monzonite contact. The lateral thrust of the monzonite magma was the only force to which these faults can be reasonably attributed.

Faults of so small displacement can not have contributed materially to the space occupied by the monzonite stock, the main exposed part of which covers more than a square mile, but other faults related to the intrusion are much greater. The best exposed of these extends eastward from near the Mammoth to the Northern Spy mine. Its horizontal component of movement is unknown though not great, but its vertical component is as much as 1,500 feet. Other east-west faults attributed to other causes are abundant in the district, but their total amounts of displacement are small and predominatingly in a horizontal direction.

Other faults caused by the intrusion are indicated by the distribution of limestone and quartzite inclusions in the monzonite, together with the offset position of a part of the rhyolite porphyry intrusion that borders the monzonite on the west. This combined evidence indicates that a large block was pushed upward and westward above the northwestern part of the monzonite, and was later largely obliterated by stoping. The amount of movement was great and may have been as much as 3,000 feet. Quartzite inclusions south and southwest of the Martha Washington mine suggest that a second block was thrust upward here as much as 2,000 feet higher than the up-thrust block noted in the preceding paragraph, and has since been completely demolished by stoping and erosion.

It is impossible to present adequately the evidence of this intrusion faulting followed by stoping without much detailed description and consideration of many points dealing with the stratigraphy and structure of the district. Let it suffice to state here that the evidence in part is clear and in part obscure. It shows,

however, that the northern part of the monzonite magma made the last few thousand feet of its upward progress largely by the faulting upward and outward of the sedimentary rocks, and that some farther progress was made by the stoping of the up-faulted blocks. Horizontal distribution of the large inclusions stoped from these blocks is abundant and such as to indicate that many of them have not moved far from their original position. The low relief of the monzonite area and absence of deep mine workings in that part of the district prevents study of the vertical range of the inclusions.

This evidence, which is limited to the northern part of the monzonite area, suggests that the whole monzonite mass may have made room for itself largely by faulting, but nothing approaching actual proof of this generalization can be offered. So far as it goes, the evidence in the Tintic district leads to the same general conclusion as that in the Cottonwood-American Fork region: that the intrusion at great depths, where the cover could successfully resist faulting, may have worked its way upward by stoping; that at some less depth, amounting at least to 2,500 or 3,000, and perhaps to many more, feet below the present monzonite surface, it forced its way upward mainly by faulting; that after the faulting had practically ceased some farther progress was made by stoping. So far as available evidence on the present surface is concerned, the faulting was of more importance as a method of intrusion than was the stoping that followed it.

As this stoping took place during the latest stage of the intrusion, it can hardly be supposed that any significant amount of "resurgent" waters or gases was derived from the sedimentary rocks at this time. Whether any "resurgent" waters or gases were derived in the early stages of intrusion, at depths below which the intrusion faulting took place, is, like the method of intrusion at those depths, a matter of speculation.

G. F. LOUGHLIN

THE "CHLORITIC" MATERIAL IN THE ORES OF SOUTHEASTERN MISSOURI.

Sir: Winslow, Buckley and others frequently refer to the presence of "chloritic material," or to "chlorite" in the lead mining region of southeastern Missouri. All mention the close association of the disseminated galena with this material.

The "chlorite" occurs in the lower part of the dolomitic Bonneterre formation of Middle Cambrian age just above the contact with the La Motte sandstone. The proportion of the mineral varies greatly, and the beds containing it may reach a maximum thickness of one hundred feet.

Doubts as to the chloritic character of this material led to the study of its optical, and chemical properties by the writer.

The mineral associates of the "chlorite" are dolomite, quartz, galena, minor amounts of sphalerite, with small amounts of argillaceous and carbonaceous material. The "chlorite" itself occurs most frequently in granular particles varying from a fraction of a millimeter up to several millimeters in diameter. Most of the grains have a very fine cryptocrystalline structure, while others consist of irregular masses or of radial aggregates. In some of the shaly portions of the beds green grains of very small size show a distinct crystalline structure.

The cleavage of these grains is distinct in one direction but is not perfect, nor lamellar. Many of the grains appear to be uniaxial, but others are clearly biaxial with a small axial angle. The extinction is usually parallel to the cleavage, but appears in some cases to make a small angle with the cleavage. The optical character is negative in all cases. The index of refraction lies between that of the ordinary and extraordinary rays of dolomite, being somewhat above 1.60. The birefringence is moderately high and lies between 0.02 and 0.03. The color is in most cases a clear grass green, and the pleochroism varies from a straw yellow to a dark grass green, with the greatest absorption parallel to the cleavage. An approximate test for potassium indicated the presence of about 9 per cent. of K_2O.

From the foregoing it is clear that the mineral can not be chlo-

rite. Its associations are not those of chlorite. Its cleavage is very different, and its birefringence is far higher than that of chlorite. The presence of large amounts of potassium excludes the possibility of chlorite. On the other hand, its mode of occurrence, cleavage, pleochroism, optical character, and chemical composition point conclusively to glauconite.

Glauconite may be formed simultaneous with or subsequent to the deposition of the original sediments of the rocks in which it occurs, but in either case it is believed that organic matter played an important part in the process. The close association of galena and glauconite seems to show a direct connection between the formation of the two minerals, and to support the theory that the ores in this district were precipitated with the aid of organic matter.

C. S. Ross

UNIVERSITY OF ILLINOIS,

Sir: That an engineering degree in geology corresponding to the degrees M.E., C.E., Mech.E., etc., is desirable, I think, admits of no question. That it should not be geological engineer, I think, is also evident, since in case this degree should be adopted for the professional degree in geology, it would undoubtedly be expected to be granted by engineering colleges—and that, to my mind, would destroy its value. The proposed degree should stand for a practical knowledge of geology, especially of economic geology, and as much of mining as is necessary to enable its recipient to appreciate the limitations placed upon the utilization of geological materials by the necessity of extracting them in proper form for market at a cost which is not prohibitive.

The training should be thorough—certainly as thorough as that required for the Ph.D., but of a different kind. It should deal with theory and the application of theory, but should be comprehensive rather than detailed. It should require a less exhaustive knowledge of the literature than is required for the Ph.D., but a fairly complete knowledge of field methods. Such a course would require an undergraduate training in chemistry, physics, the elements of mining, mineralogy and geology, and two years graduate

work in stratigraphic, structural and metamorphic geology, petrography, mining, and concluding with a thorough discussion of the principles of economic geology, and a report on some field problem. The report need not be in form for publication, but it should be accurate and sufficiently complete and illuminative to furnish such information about the region discussed as would warrant an opinion as to its availability as a source of material of economic value. In all the work, stress should be placed on theoretical conceptions rather than upon their practical application (but the latter should by no means be neglected), and upon broad principles rather than upon details. Further, and emphatically, the candidate, before receiving the degree, should be made to prove his ability to write understandable English.

W. S. BAYLEY.

Sir: The profession of mining geologist is undoubtedly becoming of more and more importance as the application of the science of geology to mining becomes more intimate and widespread, but in my opinion no special degree should be granted by a university for the purpose of specially marking out a man who has followed such a course. We have at McGill University some eight courses representing separate branches of engineering, electrical engineering, mining engineering, metallurgical engineering, chemical engineering, civil engineering, etc., but upon the completion of the four years course in each of them the same degree of bachelor of science is conferred, although in the diploma a statement is made designating the course which the student has followed, thus, bachelor of science (in civil engineering). The student if he desires to spend a fifth year in special study of the work of his course may obtain the degree of master of science, and if he desires to devote two additional years to the work, he may obtain the degree of doctor of philosophy by following a wider, more extended and more advanced course in the particular branch of engineering for which he wishes to fit himself.

In the course of mining engineering we allow special geological options so that a man who wishes to train himself more especially for the geological side of mining may do so while obtaining the degree of bachelor of science in the course of mining engineering.

We are of the opinion at this university that it is not a disadvantage to have the degrees "embrace a wide scope," and the fact that they are "not explicit" is considered to be rather in their favour. We do not feel that anything is to be gained by multiplying degrees, since we cannot exactly express the character of the course which a student has followed, and should we attempt to do so it would be necessary in the wide fields of engineering, medicine and law to grant a host of degrees which would become ridiculous in their number and complexity. For instance, in medicine dozens of degrees would have to be granted if we desired to express exactly the courses which men had followed to qualify themselves for even comparatively wide specialties in that science. The degree, like the rank, may be the guinea's stamp, but the guinea may be used for many purposes provided only the gold is there.

FRANK D. ADAMS.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

SIDNEY PAIGE.

METALLIFEROUS.

GOLD.

The Far East Rand. By E. T. MELLOR. The Mining Magazine, December, 1915, Vol. XIII., No. 6, pp. 313–320.

As a result of studies made for the Geological Survey, it is found possible to correlate the reefs found in the Far East Rand. The Van Ryn, Brakpan, Springs, Daggafontein, and Nigel are all found to be one reef, the "Main Reef Leader" of the Central Rand. There are barren and rich patches disposed in areas with the major axis northwest-southeast and this is held to be consistent with the delta theory of formation of the Rand deposits.

Pre-Cambrian Gold Fields of Central Canada. By J. B. TYRELL. Trans. of the Royal Soc. of Canada; Series III., Vol. IX., 1915.

A review of the geologic and mineralogic occurrence of gold in the pre-Cambrian of Central Canada. An important suggestion is made that the existence of a single epoch (the Algoman period) in the pre-Cambrian, characterized by the formation and presence of veins carrying gold may be of service in assisting in the determination of the age of other formations in these old rocks, where so many criteria which can be used in the determination of the age of later rocks are not available.

COPPER.

Report on the Copper Deposits of the Eastern Townships of the Province of Quebec. By J. AUSTEN BANCROFT. Department of Colonization, Mines and Fisheries, Quebec. 9 plates, 10 figures, and a map.

The results of three and a half months of field work and a careful study of the operations that have been conducted. The character of

the deposits is for the first time made clear; *i. e.*, that the majority of these deposits are associated with intrusive igneous rocks and their schistose equivalents. No true bedded deposits are present. A few of the ore bodies occur in the form of veins, but the majority are either impregnations, replacement or contact deposits. Misconceptions regarding the type of ore body has in the past led to much useless work. From the point of view of the copper mining industry in the eastern townships, that which is most desirable at the present time is a vigorous prospecting campaign. At the present time only two copper mines are steadily producing ore.

ZINC.

Origin of the Zinc and Lead Deposits of the Joplin Region, Missouri, Kansas, and Oklahoma. By C. E. SIEBENTHAL, U. S. Geol. Survey Bull. 606. 274 pp., 11 plates, 16 figures.

The lead and zinc deposits of the Mississippi Valley are of great importance, and have long been intensely interesting to students of ore deposits. The thesis of this report is that the ores were derived from the Cambrian and Ordovician rocks and deposited by an ascending artesian circulation of alkaline-saline waters containing free carbon dioxide and hydrogen sulphide. In the thorough discussion of the artesian circulation, of the zinc and lead contents of the deep waters, and of the chemistry of the ore-depositing solutions, important evidence has been brought forward to support the theory. A full presentation of the evidence will require an account of the general geology of the region, with detailed descriptions of mines. It is intended to publish these data in a supplementary volume at a later date.

IRON.

Geology of the Kiruna District (5). Origin of the Iron Ores at Kiruna. By REGINALD A. DALY. Vetenskapliga och praktiska undersökningar I Lappland, Stockholm.

This paper emphasizes a new point of view regarding the "inclusions" of ore in the Kiruna quartz porphyry, to the end that the writer believes in their endogenous nature; and with this important conclusion in mind, ascribes an origin to the ore bodies somewhat different from that held by the several students of these famous deposits; to wit, that the ores are magmatic differentiates at the base of the quartz porphyry, this latter conceived of as the upper member of a composite laccolith intruded into a pyroclastic series of rocks. Data in published memoirs and the observation of the writer during a nine-day visit to the field are drawn upon to support this view. The paper of 31 pages is illustrated by a map and cross section, and several diagrams.

REGIONAL.

The Geology and Mineral Resources of the Buller-Makihinin Subdivision. (West Part Division.) By PERCY GATES MORGAN and JOHN ARTHUR BARTRUM. Geological Survey Branch, New Zealand, Bull. No. 17 (new series). Wellington, 1915.

A comprehensive report on the geology and mineral resources of the subdivision which includes the whole of the Buller coal field, as well as less important mining areas. Large number of plates, figures, and maps.

The pre-eminent mineral asset of the district is coal of Tertiary age, though some auriferous quartz veins are present.

L'industrie minerale de la Tunisie, with an economic map of Tunis. By A. DE KEPPEN. Paris, 1914, Comité Central des Houilleres de France, 55 Rue de Chateaudun.

A compilation describing the development of the mining industry of Tunis. Leading in importance are the deposits of phosphate of lime. There are also mines of zinc and lead, and other metals.

Mineral Resources of Minas Geras (Brazil). By A. F. CALVERT. 100 pp., 127 plates. Spon & Chamberlin, New York, 1915. A comprehensive compilation.

NON-METALLIFEROUS.

OIL.

Geology and Oil Resources of the West Border of the San Joaquin Valley, North of Coalinga, California. By ROBERT ANDERSON and ROBERT W. PACK. Bulletin, U. S. Geological Survey, No. 603, 1915. 14 plates, 5 figs., 217 pp.

Presents the geologic evidences of the existence of petroleum in the rocks along the foot hills that form the western border of the San Joaquin Valley, California, between the Coalinga oil district and Livermore Pass.

"The oil-bearing zones of this region are the two diatomaceous and foraminiferal shale formations—the Moreno (Upper Cretaceous) and the Kreyenhagen (Oligocene?)—and the sandy beds lying immediately above them. This fact points significantly to the two formations as the sources of the oil, and the writers firmly believe that the petroleum was derived from the organic matter once contained in the myriad shells of minute organisms of which these formations are largely composed."

The main geologic reasons for this conclusion are convincingly set forth.

The Oil and Gas Fields of Ontario and Quebec. By WYATT MALCOLM. Memoir 81, No. 67, Geology series; Geological Survey of Canada, Ottawa.

POTASH, SALT, AND RADIUM.

The Potash Deposits of the Sand Hills Region of Northwestern Nebraska. By VICTOR ZIEGLAR; Colorado School of Mines Quarterly, Oct., 1915. Vol. 10, No. 3.

Certain alkali lakes found in part of the Sand Hills region of Nebraska, contain a decided enrichment of alkali salts, and are being exploited at the present time. These lakes owe their origin to a combination of sand dune topography (depressions without outlet) and sufficient rainfall to partly fill these depressions. The growth of the lakes, from youth to maturity, is discussed, and many analyses of the brines are given. The source of the potash and sodium salts is ascribed to the ashes of vegetation destroyed by repeated fires which in the early days of Indian occupancy swept over these areas. A description of the concentrating plant accompanies the paper.

Salt in Cheshire. By ALBERT F. CALVERT. E. & F. N. Spon, Ltd., London. Spon & Chamberlin, New York.

A monographic account of the salt industry in Cheshire, England. 1,201 pp., profusely illustrated.

Determinacion del Contenido radioactivo de las sales en las aquas las Atlantico y der Pacifico. By URBANO MIALOCK. Anales de la Sociedad Cientifica Argentina, May-June, 1915. Entregas V–VI., Tomo LXXIX., pp. 267–275.

A preliminary study showing, among other things, that the radium content of sea water varies with geographic position. Methods of research are described and results tabulated.

WATER.

Water Resources of the State of Oregon. Bull. No. 4, Office of State Engineer, Salem, Oregon.

Las aguas Subterraneas de la Ciudad de Buenos Aires. Estudio Quimico bacteriologico, geologico é higiénico. By ATILIO A. BADO. Anales de la Sociedad Cientifica Argentina. Entregas V.–XI., 1914, I., II., III., IV., 1915. Tomo LXXVIII. and LXXIX.

QUARRIES.

The Quarry Materials of New York,—Granite, Gneiss, and Marble. By D. H. NEWLAND. New York State Museum Bull. No. 181, Jan. 1, 1916.

THEORETICAL.

Le problème de l'origine des pétroles. By M. JEAN CHAUTARD. Bull. et Comptes Rendus Mensuel de la Société de l'industrie minéral. Juillet, September, 1915.

Reaches the conclusion that petroleum is of organic origin and associated with littoral sediments, these being the result of intermittent transgressions and recessions of the sea and a favorable locus for the accumulation of organic matter.

STATISTICAL.

Mineral Resources of the United States, for 1914. Part II., Non-metals. U. S. Geological Survey.

The Production of Iron and Steel in Canada, 1914. Canada Dept. of Mines, Ottawa.

The Mineral Industry during 1914. Vol. XXIII. Edited by G. A. ROUSH. McGraw-Hill.

The Production of Metals and Ores in 1913 and 1914. By J. P. DUNLOP. Mineral Resources of the United States for the calendar year 1914. Part I., pp. 415–425.

SCIENTIFIC NOTES AND NEWS

R. W. BROCK, formerly director of the Canadian Geological Survey, is major in the Seaforth Highlanders of Canada.

POPE YEATMAN has gone west to inspect Guggenheim properties in California, and the Ray Consolidated and Chino properties at Ray, Ariz., and Santa Rita, N. M., respectively.

L. D. RICKETTS has just returned from an extended trip to Chile, Bolivia, and the Argentine Republic.

J. S. DILLER, of the Geological Survey, and Arthur L. Day, of the Geophysical Laboratory, recently addressed the Geological Society of Washington on "Lassen Peak."

H. H. STOEK, of the University of Illinois, has been appointed a member of the commission authorized to consider legislation concerning mines.

A. H. BROOKS, H. G. FERGUSON, SIDNEY PAIGE and J. F. HUNTER, JR., of the U. S. Geological Survey, are at the military training camp which is being held at Fort Oglethorp, Ga., during May.

J. S. HOOK, instructor in economic geology at Cornell University, has accepted a position as oil geologist with an Oklahoma company.

E. S. MOORE, of Pennsylvania State College, lectured at Cornell University on April 26 on the "Mining Regions of Australia and India."

E. V. MONNETT, instructor in geology at Cornell University, has been appointed assistant professor of geology in the University of Oklahoma.

J. F. KEMP continues to improve slowly.

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.